GEOLOGY of New Haven Region, DANA

Dr Wilson

with the kind regards of

the Author

ON THE

GEOLOGY OF THE NEW HAVEN REGION,

WITH SPECIAL REFERENCE TO THE

ORIGIN OF ITS TOPOGRAPHICAL FEATURES;

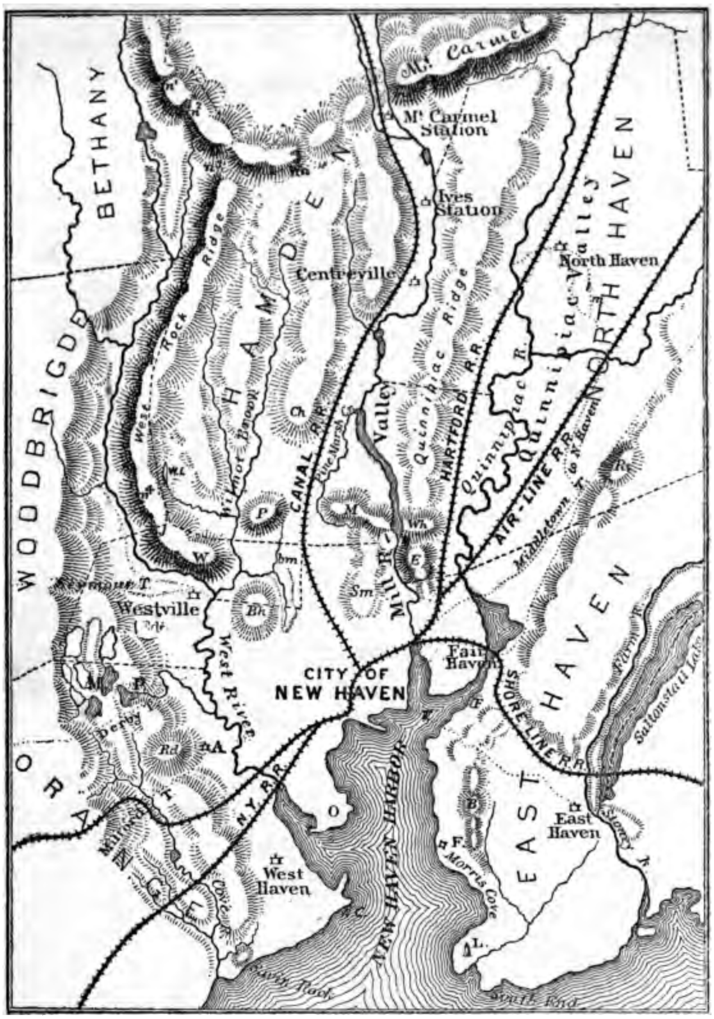
SHOWING
BY SPECIAL FACTS,
AND BY THE COURSE OF EVENTS
THAT THE REGION, IN THE GLACIAL ERA, LIKE THAT OF NEW
ENGLAND TO THE NORTH, WAS MOULDED AT SURFACE LARGELY
BY THE ACTION OF THE CONNECTICUT VALLEY GLACIER AND ITS
UNDERFLOWING STREAMS, AND COVERED, THROUGH THE SUBSE-
QUENT MELTING OF THE ICE, WITH STRATIFIED AND UN-
STRATIFIED DRIFT FORMATIONS SIMULTANEOUSLY:
THAT ICEBERGS
HAD NO PART IN THE MATTER,
AND THE SUPPOSED ICEBERG SEA OVER NEW ENGLAND
NO EXISTENCE.

BY

JAMES D. DANA.

[From the Transactions of the Connecticut Academy, Vol. II.]

NEW HAVEN:
TUTTLE, MOREHOUSE & TAYLOR, PRINTERS.
1870.



TOPOGRAPHICAL MAP OF THE NEW HAVEN REGION.

Explanations.—A, Allingtown village. B, Beacon Hill. Bh, Beaver Hills. Ch, Cherry Hill. E, East Rock range, consisting of East Rock proper to the northwest, Indian Head, and then Snake Rock. Ed, Edgewood, the estate of Donald G. Mitchell, Esq. F, Fort Hale *F*, Ferry Point, or Red Rock, on the Quinnipiac near its mouth. J, Judges' Cave, on the West Rock ridge. L, Light House. M, Mill Rock. M P, Maltby Park, only three of the proposed lakes of which are constructed. O, Oyster Point. P, Pine Rock. Rd, Round Hill. Rt, Rabbit or Peter's Rock. Sm, Sachem's ridge. T, Turnpike; also Tomlinson's bridge, across the head of New Haven bay. V, the village of Whitneyville. W, West Rock, the south end of West Rock ridge. WC, West Cape, or West Haven Point. Wh, Whitney Peak. WL, Wintergreen Lake, just north of Wintergreen Falls. Wn, Warner's Rock.

bm, Beaver Pond Meadows; *m*, Mineral Spring, southeast of North Haven; n^1, n^2, n^3, n^4, different notches in the West Rock ridge; n^1, n^2, the upper and lower Bethany Notches; n^3, the Hamden Notch; n^4, Wintergreen Notch. The names of the towns ORANGE, WOODBRIDGE, BETHANY show the course of the Woodbridge plateau; and from W in the word Westville to Savin Rock is the course of the Edgewood series of hills, the eastern border of the plateau.

Scale 4-10ths of an inch to the mile.

From the Author.

[From the Transactions of the Conn. Acad. of Arts and Sciences, Vol. II]

On the Geology of the New Haven Region, with special reference to the Origin of some of its Topographical Features. By James D. Dana.

WITH A MAP.

1. The New Haven region.

Either side of New Haven bay,—an indentation of the coast about four miles in depth,—there is a north-and-south range of hills, the trap and sandstone ridges of East Haven and North Haven on the east, and the eastern portion of the Woodbridge plateau on the west; and these make the eastern and western boundaries of the New Haven region. Their height, which is greatest to the north, probably nowhere exceeds 600 feet. The width of the region varies from about four miles on the south to seven on the north, and the whole length from the Sound to Mt. Carmel—its true northern topographical limit—is twelve miles. The northern half of the region is divided longitudinally by two lines of ridges: (1) the long West Rock trap ridge near the western side, four hundred feet and upward in height; and (2), nearly midway in the area east of West Rock, the short isolated East Rock (E) range of trap and sandstone, and the continuation of this range northward to Mt. Carmel in the low Quinnipiac sandstone ridge which divides the waters of Mill River and the Quinnipiac. The New Haven region hence consists in its northern half of three subordinate north-and-south regions; (1) a narrow valley west of West Rock, drained by West River; (2) a broad central plain (the Hamden plain), continuous with the New Haven plain, rising into hills to the northward, and drained along the east side by Mill river; and (3) a wide eastern portion occupied by the river-course and the extensive meadow lands of the Quinnipiac, in other words, the wide valley of the Quinnipiac. South of East Rock, the central New Haven plain blends with that of the Quinnipiac. The West Rock ridge to the north throws off a branch on the east which curves around to Mt. Carmel and forms the northern boundary of the central of the three subordinate regions. This central region is partly subdivided across, on a line, nearly, with West and East Rocks, by two short trap ridges; Pine Rock, (P) a third of a mile from West Rock, and Mill Rock, (M) which adjoins East Rock; the width of the interval between the two is nearly a mile. Mill River passes through a deep cut in the Mill Rock ridge, at the village of Whitneyville. A clear idea of the topography of the region

is necessary in order to an appreciation of the observations that follow.

2. General course of Geological events before the Post-tertiary era.

One of the last events of the Paleozoic ages was the formation of the Connecticut River valley, by the bending of the earth's crust; and this took place as a sequel to, or in connection with, the crystallization of the granite, gneiss, crystalline schists, and other similar rocks, which make the bottom of the valley.

The first fact of the *succeeding* age, the Reptilian, of which there is record, is the existence of a Connecticut valley estuary, twenty miles or more wide, stretching from New Haven to northern Massachusetts, (New Haven being the proper southern termination of the valley and estuary), and the commencing deposition in this estuary of the Red Sandstone formation. The production of this formation is believed to have taken the whole of the Triassic period, the first period of the Reptilian age, and also part of the next or Jurassic period.

After, if not before, the close of the Sandstone era there were eruptions of trap—a rock that came up melted through wide fissures in the sandstone and subjacent rocks. East and West Rock, Pine Rock, Mill Rock, Mt. Carmel, the Meriden Hills, are ridges of trap along with what remains of the old sandstone walls. The sandstone in the vicinity of the dikes, or near any fissures, through which heat and vapor escaped, was more or less hardened by the heat, and rendered comparatively durable; while other portions were left unhardened or but little so, and therefore in a state admitting of easy erosion and removal. Cotemporaneously with the ejections of trap, veins of copper were made, as those of Bristol, Simsbury, Cheshire, etc.; and veins of barytes, as those of Cheshire.

The thickness of the sandstone formation in the New Haven region is not yet ascertained; in Massachusetts, it is according to the lowest estimate three or four thousand feet. There is abundant evidence that its beds once covered the top of East Rock, now 360 feet in altitude, and if so it reached upward to a level which is now at least 400 feet above the sea. Many of the trap ridges to the north in the Connecticut valley were also once topped with sandstone, although much higher than East Rock. West Rock has a height of 400 feet, and the West Rock ridge, between Hamden and Woodbridge, over 500 feet; Mount Carmel about 800 feet; Middletown mountain is 899 feet high; West Peak, the western summit of the Meriden Hanging Hills, 995 feet; Mount Holyoke 985 feet, but the highest point of the Holyoke ridge, a little farther to the east, 1126 feet; and Mount

Tom, 1211 feet. (The last four altitudes are from Prof. Guyot's measurements.) Although the precise original elevation of the sandstone about these heights is not certain, there is no doubt of the great increase of height to the north. This however was not one of the original conditions of the rock, for the beds were made in one common estuary and nearly to a common level. It has resulted from an uplift which affected the interior of New England more than its southern borders; and the trap also owes much of its greater height to the north to the same uplift.

The sandstone mass intersected by dikes of trap constituted the block out of which the future New Haven region was to be carved by various denuding forces. The hard dikes of trap, and the distribution of the hardened sandstone among those feebly hardened, had great influence in guiding the modeling agencies and determining the future features of the country.

At the time of the eruptions, or soon after, the land before submerged rose above the level of the waters; rivers took size and direction according to the slopes; the estuary dwindled into the Connecticut; and the Connecticut, finding in its way the trap dikes of Weathersfield, Berlin and Meriden, and also elevations of sandstone, took a route, in the latitude of these hills, to the eastward. So the river was lost to New Haven.* Other changes in the old hydrographic basin of the Connecticut valley have taken place since the throwing up of the trap dikes, and part of the following may date from that event. Farmington river, which in Triassic times flowed into the estuary from the western heights of Massachusetts and northern Connecticut, still enters the Farmington region; but near Farmington it turns abruptly *north*, flows in that direction sixteen miles, at the foot of Talcott mountain and other trap hills of the range, then makes a cut through the range into the Connecticut river valley and joins that river. The Quinnipiac, which starts in the Farmington valley just below the northward bend of the Farmington river, on approaching the region of the trap hills of Cheshire bends eastward out of the valley in front of the Hanging Hills of Meriden, into the valley where the Connecticut river might have had its course but for the trap eruptions and disturbances; and finally, the Farmington valley being thus deserted by the Quinnipiac, Mill river at this point commences its flow, taking its rise in the adjoining hills, and becomes the principal stream for the rest of the valley southward to New Haven bay.

During the Cretaceous period closing the Reptilian age, and the

* This view was brought out by the writer in Ward's Life of Percival, p. 420.

Tertiary period which opened the Mammalian age, no marine formations were here made; and there is hence no proof that in the long interval between the origin of the trap dikes and the Glacial epoch, the land of the region, or of any part of central New England, was at any time under the sea. Whatever the fact, there must have been, during the time that elapsed, a large amount of denudation over the region; so that West Rock, Pine Rock, Mill Rock and East Rock finally became prominent above the plain, although much less so than now.

3. General character and results of the Post-tertiary period.

Next came the Post-tertiary period, the last in Geological history. In order to understand the following remarks it is necessary to bear in mind that the Post-tertiary in America, as the writer has elsewhere shown,* included three eras, corresponding to three great changes of level over the northern portion of the Continent.

1. The *Glacial* epoch; when the land stood at a *higher* level than now, and a universal glacier and a frigid climate covered the continent north of the parallel of 40°, (not a sea with icebergs, as facts about New Haven demonstrate.) 2. The *Champlain* epoch, an era of subsidence; when there was a sinking of the land below its present level, resulting in a mild climate and a melting of the great glacier; submerging beneath the sea the land along the coast, and giving great extent to lakes and rivers. 3. An epoch of elevation; bringing the land up to its present level, and raising the submerged sea-shore and river flats to a habitable and cultivable height, thus making them available for man. The movements were up—down—up; *up* for the *Glacial* era, *down* for the era following, and *up* again for the third or finishing era. The origin of the features of the New Haven region cannot be understood without keeping constantly in view these three great movements of the land. In the first of these eras this region stood probably one or two hundred feet *above* the level of the sea; in the second sixty-five feet or more, and afterward forty and less, *below* the present level; and in the third it passed gradually to its present condition.

With reference to the question whether icebergs may not have been the agent in the glacial era instead of glaciers, a single argument only need here be brought forward. Icebergs, as is well known, are fragments of glaciers broken off in the sea into which they descend; and the freight of stones and gravel they bear was received mainly when they were in the glacier condition. The boulders of the Connecticut

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* Am. Jour. Sci., II, xxii, 325, 346, 1856, and Manual of Geology.

valley if brought by icebergs, should hence have come from the White Mountains, or perhaps from some Green Mountain peak, for these would have been the only summits above the water in a sea covering the valley to a depth of four thousand or more feet (the depth that the distribution of boulders requires). But, on the contrary, the boulders of the New Haven region, 1000 tons and smaller in size, are mainly from the trap and sandstone hills of the valley itself, either in Connecticut or Massachusetts, and the adjoining plateau of gneiss, etc.; they are from the depths of the imagined sea, and not from the heights above it. Icebergs could not therefore have done the work of transportation. In the Glacial era, then, all New England and, probably, the whole northern portion of the continent, was covered with ice. It is well known that the Glacier theory is sustained by the explorers of the Alps, Professors Agassiz and Guyot.*

4. Condition and Effects during the Glacial era.

The Connecticut valley glacier lay under the general glacier-blanket of the continent, or rather was a part of the lower portion of it. It extended from the summits of the Green Mountains on the west to the dividing height of land on the east, having a width of 100 to 120 miles; it was therefore sufficiently large to have almost entirely an independent motion, determined by the slope of the valley; which would make the prevailing direction of movement southward, or mostly between south and 12° west of south.

The direction, according to Prof. Hitchcock, of the scratches on Mt. Monadnoc in New Hampshire, which extend even over its summit 3,718 feet in altitude, is southward; and the same authority gives this as the course in Deerfield, Greenfield and other places in the Connecticut valley, as well as on Mt. Tom and Mt. Holyoke. It is the course also in one of the gorges of Mt. Carmel. East of the Hanging Hills of Meriden it is south-southwest, and Percival attributes the unusual amount of westing to the trend of the adjoining

* Dr. Newberry, in an excellent paper on the Surface Geology of the Great Lakes and the Valley of the Mississippi (Ann. Lyc. N. York, ix, 1869), sustains the glacier theory of the drift for the country, but gives reasons for making part of the area of the Great Lakes an *iceberg* region in the closing Glacial era. The author presents many other points of interest with regard to the successive events of the Glacial and Champlain eras, and in the course of his remarks, observes that there could have been no true lateral moraines. He makes the depositions of drift over the hills and the stratified material of the valleys and plains essentially cotemporaneous, regarding them as having resulted partly from iceberg transportation, and partly from distribution by waters flowing away from the margin of the ice, or from beneath it, as it slowly melted.

trap hills. Some deviation from the general course would take place wherever there are high ridges or deep valleys varying in direction but little from the main course of the movement, just as a deep trough in the bottom of a stream of water set a little obliquely to the current would deflect the waters and give them more or less nearly its own course;* and this is what Percival observed in the valley between the Hanging Hills of Meriden and Lamentation Mountain. In East Haven, on the eastern border of the New Haven region, the direction is S. 13° E. The facts sustain the conclusion that the general course was that of the Connecticut river valley. To the westward of the central portion of the valley, over the eastern Green Mountain slope, the general course, as various observers have shown, is to the *east* of south, or about *south-southeast*, which is a natural resultant of the two forces—that producing the main southerly movement, and that arising from the eastward, or E. by S. slope of the surface.

As the slope southward was very small compared with that in the Alps, the motion was much slower—probably not exceeding a mile in a century, which is equivalent to about a foot a week. The movement was not continuous at this rate, but by starts, at longer or shorter intervals—weeks, months or years—as the resistance could be overcome. Having a thickness to the north of more than four thousand feet, the pressure it exerted wherever its lower surface rested was enormous, and when it did move the abrasion was commensurate with it. It was not, like an Alpine glacier, confined between the sloping sides of a valley, the declivities of which aided largely in its support, and so relieved the bottom partly from pressure; it lay spread out over the plains and hills resting heavily upon the most of the surface beneath it.

The movement produced three results, as has been well illustrated by the principal authorities with regard to glaciers. First, a breaking of the brittle ice wherever there was friction, resulting in opening immense crevasses where the resistance was great (for the glacier owes its power of movement to the facility with which it breaks and mends itself); secondly, the abrasion of the rocks beneath, resulting in a ploughing out of the soft half-hardened sandstone to

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* In the case of *large* continental valleys, the glacier followed the course of the valley even when this course was east-and-west, as is shown by the author to have been true of the Mohawk valley, in his Geology (p. 751), and in the American Journal of Science, [2], vol. xxxv, p. 243, and by Dr. Newberry, with reference to other regions, in the paper referred to on the preceding page.

great depths,* and less deeply the harder rocks, and in dislodging masses from the dikes and other rock formations which had been previously loosened in any way, the masses sometimes many tons in weight; thirdly, the taking up of the sand or gravel, stones and rocks, thus separated or dislodged, into its own mass, which it was enabled to do because of the attendant breaking up of the ice just alluded to, and the readiness with which ice becomes solid again by regelation after a short rest. Thus the glacier moved slowly on, engorging itself with whatever loose material it made, as well as with what it found in its path.

The glacier was made ready for its great work of abrasion either in the way of rasping, planing, channeling or ploughing through the sand, stones and rocks with which it was shod. The hard granite rocks east of New Haven, as is exhibited at Stoney Creek, were marked by the glacier not only with scratches but with broad furrows six inches to a foot in depth; and this in addition to an unknown amount of planing above the present surface. The soft red sandstone of the region easily yielded under the pressure, and was ground up and ploughed out in some places to a depth of several hundred feet, the material being absorbed at the same time into the icy mass. Hills and ridges lost much of their height, and those of trap were extensively stripped of their associated sandstone. The isolated East Rock, lying north and south, or in the direction of the movement, between the Mill River valley and that of the Quinnipiac, was abraded both along its western front and on the rear, and left nearly bare of sandstone on both sides. Pine Rock, an east and west ridge, besides undergoing an unknown amount of decapitation, lost the sandstone on its northern side for the upper sixty feet, and a wall of trap of this height is left bare. Mill Rock suffered a like fate with Pine Rock; for the north wall of the trap dike projects in places twenty or twenty-five feet above the sandstone. Whitney Peak is in like manner bare of sandstone on its north side for forty feet from the summit. At the Fair Haven sandstone quarries and over the country near the

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* While this sandstone is hard enough for an excellent building stone in some portions of the Connecticut valley, and often very hard-baked in the vicinity of the trap dikes, a large portion of that exposed to view over the New Haven region a little remote from the trap is so soft that it is easily dug up by a pick, and sometimes even by an ordinary shovel; so that we have reason for regarding the strata of it underlying the most of the New Haven plain, or its alluvium, as of this soft kind. Part at least of the hardening and reddening of the sandstone was evidently due, as stated above, to the heat that escaped in connection with the trap eruptions and from fissures opened in their vicinity; and in regions where there was no heat from these sources the rock was but little hardened.

Milford turnpike, the removal of the soil in several places has exposed large surfaces that were planed and grooved by the glacier; and there is no doubt that but for the covering of earth the rocks in all directions would be found glacier-marked.

The stones, or boulders, in the foot of the glacier, that were scratched and polished while doing this work of abrasion, are often to be found where the drift of the hills has been freshly uncovered. One of four tons weight lies on the roadside along the Milford turnpike, a few rods above Allingtown; and many others of smaller size have been thrown out at the recent excavation for the Derby railroad, near the toll-gate on the same road.

By the means mentioned an immense amount of rock material was taken aboard the glacier for transportation southward; and yet there were no *lateral moraines* in the ordinary sense of this expression. The *surface* of the Connecticut valley glacier was white and spotless. From the Green Mountain ridge to the White Mountains of New Hampshire there was not a projecting peak to afford a grain of dust.

The special effects of the glacier over the New Haven region included the making (*a*) of hills, and (*b*) of valleys or excavations.

First—*Its Excavations.*—The excavations would naturally have been most extensive where there was no trap or other hard rock in the way to prevent deep ploughing. The valleys of the Quinnipiac and West River beyond doubt date their origin long back of the Glacial era, from the time the trap and sandstone ridges which bound them were first thrown up above the level of the sea; but still they must have been scoured out by the moving ice, and have had their depth and width much increased. Whether the work of the ice or not is uncertain; yet it is a fact that the whole western side of the West river valley is stripped clean of the sandstone which once existed there, and which was a part of the formation that originally stretched across to the top of the West Rock ridge; not a square yard of sandstone is left in place over the metamorphic rocks of its western slope. The close shaving of the sandstone on the east side of East Rock, and its still more complete removal on the west side, have been already alluded to as probably part of the effects of the glacier. Besides the excavations in these valleys, others very extensive must have been made over the whole central part of the New Haven region, from its southern limits to the mountains on its northern border in Hamden; for this was the great central valley of the region.

Among the depressions over this region, the most remarkable is that of the *Beaver Pond Meadows* (*bm*, in the map). It is a large marshy area sunk 20 feet below the general surface, lying in the center of the

New Haven plane, between the trap hills, Pine Rock and Mill Rock.* It crosses the borders of the towns of New Haven and Hamden, and has a length from north to south of 1½ miles, and an average breadth in its southern half of a fourth of a mile. The basin receives almost no outside water, and yet gives exit to a stream which in its descent of 22 feet to West river affords water power to two or three manufacturing establishments. In its wide and flat meadows, and its high sloping bank of 20 to 30 feet, looking like the terrace slope of the river valleys, it appears as if it were once the course of a large stream; yet it not only receives no water at its head, but not even an old dried up channel; moreover the outcrops of sandstone less than a mile to the north afford no evidence of the former existence of such a channel leading toward the Meadows. This absence of proof that any river ever discharged itself through the depression is part of the evidence that its excavation was the work of the glacier, as explained beyond.

If the Beaver Pond depression was excavated by the glacier, we should naturally look for a continuation of the channel southward to the New Haven bay. This channel was probably that of the old *West Creek*—a valley with similar broad meadows and distinct terrace slopes, terminating in the northwest angle of New Haven bay.† Although now nearly dry throughout and covered by streets and houses, two and a half centuries since it was large and deep enough to give entrance to Whiting street for vessels of considerable size, and as far as College street for boats. The connection between the Beaver Pond meadows is cut off by the alluvium—a deposit of the era following the Glacial; but a series of large and once deep depressions lies between them and *both are in nearly the same north-and-south line.*

There are also two other broad valley like depressions leading off

* Owing to a defect in the engraving, the position of only the southern part of the Beaver Pond basin (*bm*) is given on the map. The dotted outline should have been extended northward, by the east end of Pine Rock (P.).

† East and West Creeks, as they are now obliterated channels, are not on the map. They may be put on, with a lead pencil: for *East Creek*, by drawing a line from a point just east of the southern end of the Beaver Pond depression (*bm*) *eastward* to the Canal road, then along the course of this road southward, and thence to the head of the New Haven bay west of its center; and for *West Creek*, by starting the line a little west of south of the extremity of the Beaver Pond basin and continuing it to the northwest angle of the bay. Each was about 1½ m. long; yet for half a mile the channel in both cases was a broad tidal inlet. The city of New Haven was originally laid out at the head of the bay, *between* these two creeks, the west side of its *half mile square* (George street) against the *West* Creek valley, and the south and east sides (State and Grove streets) near *East* Creek.

from near the southern extremity of the Beaver Pond basin, but to the *eastward.* One passes near Webster street, and the other by Munson street, and the two unite in the valley of the former *East Creek*, now occupied by the Canal Railroad. They are evidently continuations of the Beaver Pond depression, and it may be questioned whether these were not also courses of the Beaver Pond glacier excavation. But although broad, they are comparatively shallow and have *gently sloping* sides; and the course of each is east-and-west, or *transverse to that of the glacier movement.* We conclude therefore that they were probably a result of the tidal currents and waves of the following or Champlain epoch, and of the later action of surface waters. It is to be remembered that the glacier made its excavations in the strata underlying the superficial alluvium.

We should naturally look also for a *northern* continuation of the Beaver Pond depression. But we have already stated that the appearances at its northern extremity indicate its rather abrupt commencement at that point. Half a mile to the eastward of the depression, and as far south of its northern end, there is a broad channel leading *northward* which is the course of what is called on the map Pine Marsh Creek; and the question comes up whether this was not the *northern* part of the Beaver Pond depression, and therefore whether Mill river did not once discharge its waters through it and thence enter the bay by *West Creek* valley. The southwestern part or extremity of this great depression (situated near the junction of Goodrich street and the Canal railroad and close by the present terminus of the Shelton Avenue railroad), reaches within 300 yards of two broad northeasterly channels leading down into the eastern bays of the Beaver Pond basin. The valley is so broad, and so abrupt in the slopes which bound it, that it appears as if large enough to be the course of a river. Through its now sluggish waters, clumps of bushes rise in most parts from the shallow bottom.*

These facts *seem* to favor the conclusion that we have here actually found the northern continuation of the Beaver Pond channel. But the valley widens *northward* instead of toward the Beaver Pond depression, and the creek flows at the present time in that direction, starting just south of Mill Rock and entering Mill River 1½ miles north of Whitneyville (V.) Another view with regard to it we regard as much more probable.

* Owing to the dam at Whitneyville, the water of Mill River is not only set back for two miles and more up the valley, but also flows back into Pine Marsh Creek valley for more than a mile, to within a short distance of Mill Rock (See Map.)

At the mouth of Pine-Marsh Creek, Mill River takes a bend a little to the *eastward* of south, while the creek has a course as much to the *westward* of south, and Mill Rock stands between the extremities of the V thus made by the two channels. In this position of Mill Rock, we find the explanation of the facts referred to.

The great glacier having had its ploughing under-surface shaped by the gap west of Mt. Carmel, through which Mill River passes, moved southward, excavating the valley of Mill River, while, at the same time, abrading the soft strata over the hills and plains. The Mill Rock dike, making now a ridge 200 feet in height, stood in its path, the brittle ice confronting the unyielding trap mountain. Under such circumstances, it would have been a natural consequence that at some point north, the brittle ploughshare should have divided, the smaller part to pass toward the Whitneyville opening, by the east end of Mill Rock, and make a shallow furrow because of the hard trap rock under foot at the gap; the larger part, encountering only the soft sandstone, to plough out the deep broad valley of Pine-Marsh Creek, leading by the west end of Mill Rock and almost directly toward the Beaver Pond region.

The question arises whether the excavation was continued into the Beaver Pond basin and thence southward to the bay, or whether there was a lifting of the ploughing portion of the glacier through the elevating action of Mill Rock and merely a transfer of the excavating pressure to a line more to the westward—the process of transfer producing the six or eight bays characterizing the eastern side of the Beaver Pond depression and the broad southwesterly surface channels which lead into them. In the former case, Mill River would have run through the Beaver Pond excavation and West Creek; in the latter, the waters of Pine-Marsh Creek would always have been tributary to Mill River in its present position; for in the Glacial era they would have been those of a sub-glacier stream, and these would have become far more abundant in flow during the melting of the glacier, and thus have made a stream commensurate with the Pine-Marsh Creek valley.

There are three objections to the view that Mill River once discharged itself through the Beaver Pond Meadows. (1.) The Beaver Pond depression is prolonged half a mile north of the point where the Pine-Marsh valley makes its nearest approach to it, and this northern extremity does not bend toward the valley or show any inclination that way. There is here evidence that the Beaver Pond excavation had its own independent beginning.

(2.) If Mill River once flowed through the Beaver Ponds and thence through West Creek to the bay, the force of its waters would have continued to keep this channel open, and West Creek would not have been disjoined from the part above.

(3.) If, during the Glacial era, Mill River had had no channel through the Whitneyville gap, it could hardly have afterward gained a foothold there where the alluvium has a height of 60 feet or more above mean tide level.

There is hence not only no proof of a former connection between Pine-Marsh valley and the Beaver Pond depression, but strong reason against it in the condition and character of Mill river and its present channel.

Secondly—*The Elevations, or Hills and Ridges made by the Glacier.* Besides extensive excavations, there are also *elevations* which were due to the glacier. They were a consequence mainly of the interrupted series of trap ridges in its way. The hard trap-rock dikes, Mill Rock and East Rock, were fenders both to the sandstone lying on their northern side, and also that on the southern, and especially to the latter. The glacier, moving from the north and approaching Pine Rock, would have had its under surface forced up into an arch by the resisting mass, and the ice thus shaped would have been made firm and solid by the pressure; and as such an arching of the ice below is an arching of the abrading surface of the glacier, an elevation of sandstone corresponding to it should have been left by the glacier on its southward march. *An elevation was thus left south of Pine Rock—that of the Beaver Hills* (*Bh.*) The Hills are now disjoined from the Rock because of erosion (*a*) by the waters and ice that descended the slope during the declining Glacial era; (*b*) by the waves and marine currents of the subsequent period of submergence in the sea; (*c*) by streamlets down the declivities due to the rains and melting snows of later time when the land was elevated to its present level—an era of greater elevation or emergence. It was the eastern abutment of this great Pine-Rock arch that scooped out the Beaver Pond basin.

In the same manner the narrow north-and-south Sachem's ridge (*Sm,*) a mile and a half in length, was evidently made through the lifting action of Mill Rock. Similarly also, the small Cedar Hill, south of East Rock, owes its existence, apparently, to the arch made by the East Rock range; it is *small* because the East Rock range has a north-and-south direction, or lies with its end toward the moving glacier; and also because the ice of the wide Quinnipiac valley would have pressed westward as it escaped the limits of the valley and passed

the southern extremity of the Rock, and so have swept away the sandstone there remaining.

The great glacier did not succeed in ploughing out the Mill Rock dike at the Whitneyville notch below the level of the bottom of the present dam, for the dam is built on the solid trap dike. The ice must therefore have plunged down the front of it (the land having been higher than now), and with it the sub-glacial stream descended. South of this it appears to have made a deep Mill River channel.

The glacier acted like the moulding tool in the plough of the carpenter. But the convexities and concavities on the cutting or abrading edge of the tool were not needed in the pliant material; for by the fenders placed in its front, in Pine Rock, Mill Rock, and East Rock, the edge was made in these parts to rise or arch upward, and by this means long ridges of various heights were made beween the furrows.

The correspondence between the channeling of the plain and the position of the trap ridges is so close (especially if it is considered to what an extent subsequent river and marine action must have tended to modify the features of the surface and obliterate the tracks of the glacier) that there seems to be here visible demonstration of glacier action, and of the insufficiency of the iceberg theory of the drift.

If Sachem's ridge, the Beaver Hills and Pine Hill were the only examples of north-and-south sandstone elevations due to hard-rock fenders, the correctness of the explanation offered might be reasonably questioned. But they are the least remarkable instances. Over Hamden there are three north-and-south ranges three to four miles long, as exhibited on the map, and they may be distinctly followed northward to elevations in the transverse range of heights west of Mt. Carmel. Cherry Hill (Ch) is the termination of one of these lines. A still more striking example is the Quinnipiac ridge, the dividing ridge between Mill River valley and the Quinnipiac. It stretches from the south side of Mt. Carmel to Whitney Peak, a distance of *six miles*, and while broad and broken into hills to the north, is to the south an evenly rounded elevation, looking from the summit of Mt. Carmel like a splendid example of landscape grading. According to the theory presented, this long ridge of sandstone owes its existence to the arching upward of the ice by the high east-and-west Mt. Carmel range, the ridge being a part of the great sandstone formation left thus elevated in consequence of this arching. The arch, although narrowing somewhat, did not flatten out before reaching Whitney Peak, as the continuation of the ridge shows; and here it was raised

into a new arch by this dike, losing in the encounter the red sandstone from the back (or north side) of its head, down nearly one-third way to its base. Either side of this dividing ridge the glacier, besides abrading the general surface of the sandstone formation and thereby preparing the rocky basement for the alluvial plains, was ploughing out the river channels adjoining—that of the small Mill River on the west, and that of the broad Quinnipiac on the east. It is a strong confirmation of the view brought forward that the direction of the Quinnipiac ridge, (as well as that of Sachem's ridge,) is S. 12° W. (true course), thus coinciding with the average direction of the Connecticut valley, and therefore with that *of the movement in the glacier.*

The largest of the valleys in the Hamden portion of the New Haven region lies along side of the West Rock ridge, where the erosion of the glacier, and of the waters flowing from them would have been greatest in consequence of the height of the rock and its slopes, and where, moreover, erosion from running waters has been going on ever since from the streamlets that the rains and melting snows have made over the long declivities. In this valley lie Wintergreen Lake (due to a recent damming of one of the streams), and farther north the sites of other "contemplated" lakes.

This western part of Hamden is drained by Wilmot brook with its tributaries, which flows through the gap between Pine Rock and West Rock and soon after enters West River. The northern portion of the brook, which lies among the sandstone ridges, points southward nearly toward the northern extremity of the Beaver Pond depression, and approaches it within two-thirds of a mile. It might therefore be queried whether Pine Rock had any effect toward dividing the excavating action of the glacier on the north, like that from Mill Rock above described. But there is this great difference in the two cases, that the gap between Pine Rock and West Rock is very much broader than the Whitneyville gap, being about a quarter of a mile across, and besides there is no continuous pavement of trap at bottom. Moreover Pine Rock has an oblique position with reference to West Rock, its direction being E. 20° N. true course, (about E. 12° N., compass course,) and owing to the convergence of these two ridges and the broad opening intermediate, and also to the S. 12° W. direction of the glacier movement, the principal part of the excavating portion of the glacier would naturally have passed between them, where Wilmot brook has its actual course.

Looking beyond the limits of the New Haven region, still other *examples* of this north-and-south ridging of the soft sandstone occur.

South of the Hanging Hills of Meriden an elevation commences which stretches southward to Mt. Carmel, showing that the ice was arched up by the Meriden mountains, and the arch continued to Mt. Carmel. And here, as just observed, it was thrown anew into a high arch for the ridging and ploughing southward, in the course of which the Quinnipiac ridge was formed; then it was raised by Whitney Peak again, and its continuation East Rock; and finally it died out as it left the region of Cedar Hill south of the East Rock range.

Besides the large ridges and excavations made by the glacier, the ledges over the hills are often approximately north-and-south in course, and were probably a result of glacier ploughing. The chlorite schist of the Woodbridge plateau is easily torn up in consequence of its slaty structure and its joints or lines of fracture, and also readily reduced to fragments by the freezing of water or growing of vegetation in the crevices. A large trap dike, intersecting this rock on the Woodbridge heights west of Westville, often stands up above the schist, as a prominent ridge, which sometimes has on one side or the other a bare precipice of forty feet. But much of this wear is undoubtedly the work of subsequent centuries.

Without adducing other cases, it appears safe to conclude that over the region of the Connecticut valley the principal part of the coarse gouging out of the plains, and shaping of the mountains and valleys, were performed by glaciers and by the streams that were in action during the progressing and declining Glacial era. The same agents also carried southward the earth, sand and gravel that were afterward to be deposited by the ice, and worked over by the rivers, or, near the sea-shore by the rivers, tidal currents and waves, into terraced "alluvial" plains, or *stratified* drift formations.

Scratches having the course S. 33° W.—A wide variation from the usual course of the glacier scratches (South, to S. 12° W.) occurs over the chlorite rock along the Milford turnpike half a mile to a mile west of Allingtown. The place is about two and a half miles south of West Rock, and one and a half miles south of the line of East Rock. The course (true) of the scratches is quite uniformly S. 33° W., *or full 20° west of the usual direction;* and they are so deep and numerous and so completely free from crossings by scratches in any other direction, that S. 33° W. must be viewed as the course of the under surface of the glacier over this part of the western margin of the New Haven region. The scratches are seen at the top of the first ascent on the turnpike, about 130 feet above the sea, (or 90 above the level of the New Haven plain), and at many other points

where the rock has been recently exposed, for half a mile west. The ledges that have been long bare have lost their scratches by weathering; on this account, and owing also to the covering of soil over other parts, observations have not yet been extended farther west. The following is offered in explanation of this southwestern throw of the under portion of the glacier.

It has been stated on page 45 that the New Haven region, between the summits of the ridges confining it on the east and west, has a width of *seven* miles to the north, and narrows to *four* at the south. While the mass of the glacier was continuing its southward movement, the portion below filling this depression would have had to accommodate itself some way to the narrowing limits. This accommodation might have taken place, through an increasing depth of the depression southward. But if this was insufficient to meet the whole, there would have been a tendency to a thickening upward of the glacier and relief would have been obtained from the accumulating pressure by a lateral escape of the ice.

There was evidently no yielding or escape on the *east* or Quinnipiac side, the side of the broadest and deepest valley, and therefore of deepest or of thickest ice; for the ploughings of the glacier which are exhibited along that side on a grand scale over the East Haven sandstone, have the usual southward (S. 13° W.) course. Hence the escape, if any where, must have been on the west side; and here it is that we find these S. 33° W. scratches. The place is southwest of where the Quinnipiac valley opens on the New Haven plain, and consequently it is situated just where such an effect from the expansion and pushing action of this part of the glacier would be produced. Now to the *west* of the region of these scratches within three-fourths of a mile, there is the rather broad valley of Cove river, which extends southward and reaches the Sound two and a half miles below; it is parallel nearly with the New Haven region, but *has a much steeper slope*, the descent to the salt water flats being at the average rate of about 125 feet in a mile. This slope of the valley would have given the ice that filled it (the under portion of the glacier, if not the whole above) relatively a rapid movement. The overflow from the New Haven depression caused by the conditions stated would therefore have naturally taken a course into this valley. The direction of the scratches, S. 33° W. accords well with this view.

Making of Lake-basins.—The lifting of the lower or abrading surface of the glacier by hard rocks, which has been shown to have resulted in the production of the north-and-south ridges, and which ap-

pears to have terminated southward the basin of Pine-Marsh Creek, might under other circumstances have made basins for lakes. Lake Saltonstall, four miles east of New Haven, probably owes its existence to this action. The lake is 3½ miles long and has an average breadth of a third of a mile. The basin is scooped out of a very soft, crumbling shaly sandstone, and lies between two bow-shaped trap dikes, three-fourths of a mile apart, whose average trend is north-northeast. Its depth is stated at 112 feet; and since its surface is only half a dozen feet above high-tide level, the bottom is more than 100 feet below that level. At the present outlet the waters flow over solid trap at a low cut in the western trap ridge, so that the basin is here rock-bound on the south. The stream from the lake (called Stoney River, but properly the lower part of Farm River), flows for its last mile between granite shores and has in some places a rocky bottom. Thus there is a granite as well as a trap barrier between the lake and the sea, and the depression it occupies is a true basin. We may believe therefore that the long narrow basin occupied by the lake is an excavation made in the soft sandstone by the ploughing glacier, and that it was not continued to the sea because the ploughshare was lifted out of its trench by the hard unyielding rock before it.

Height of the Land in the Glacial era.—With regard to the height of this portion of Connecticut above the sea in the Glacial era we have as yet few facts for definite conclusions.

a. In sinking an artesian well on Green st., 120 yards from the harbor, a bed of fine clay 14 feet thick was struck at a depth of 140 feet, or 126 feet below mean tide level. Above this clay there were the ordinary sand or gravel deposits of the New Haven plain. The clay bed was evidently a mud deposit made in the harbor as it existed immediately before the deposition of the sand; and as the sand beds of the New Haven plain date from the era following the Glacial, the harbor very probably was that of the Glacial era. If the land then stood 125 feet above the present level, the mud bed would have lain just at the water's surface, like those of the present day. The evidence as to the level of the land in the Glacial era is uncertain; still it affords a presumption that it was at least 125 feet higher than now. No clay has hitherto been found in any other part of the New Haven plain.

b. Near Stoney Creek, eleven miles east of New Haven, on Smith's Island, one of the "Thimbles," there are two pot holes in the hard gneiss rock; one of them is 7½ feet deep, and 3 in diameter, and the other 3 feet deep and 10 inches across. They are situated within a

few yards of one another upon the coast, but above high tide level. The large one contained, when recently opened by Mr. Frank Smith, its discoverer, many large rounded stones. Another pot hole of less depth exists upon Pot Island, about a mile to the southeast of Smith's Island. It is like a bread-trough in shape, and is 4 and 2 feet in its diameters, and 1½ feet deep. Still another, as I am informed, occurs on Rogers' Island, one of the westernmost of the same group. It is within reach of the tides and is 4 feet deep and 2 in width. These pot holes must have been made by torrents from the land. For the existence of such torrents the land should have been above its present elevation. We cannot fix positively the era of this higher level, but it may have been that of the great glacier, and the torrents, sub-glacier streams then existing.

c. The valleys of the streams of Connecticut and even those of the north side of Long Island are in general continued over the bottom of the Sound beneath its waters, apparently excavated for the most part out of the sand and mud deposits which constitute it; and this fact appears to indicate that the Sound was once dry land—a great east-and-west depression of the surface—into which the streams of the adjoining country flowed, and there concentrated their waters in a grand central river which received the existing Connecticut a few miles before entering the Atlantic. The admirable chart of the Sound by the U. S. Coast Survey, which is covered with figures indicating the soundings, enables any one interested in the subject to draw the lines of equal depth, and verify this statement.* There is nothing in the depth of the Sound to render the above supposition incredible. An elevation of 100 feet would now lay bare all but a fifth of its bottom across from New Haven, and one of 140 feet the whole breadth; and one of 200, would dry it up all the way to the line of New London, 50 miles east of New Haven. Further, a rise of even 50 feet would wholly separate the narrow western portion of the Sound from the more eastern by a bare area in the meridian of Marmaroneck and Rye, or 50 miles west of New Haven. Only the broader depressions corresponding to the courses of streams are to be looked for over the bottom, even with the fullest possible series of sound-

* It is best, in order to exhibit well on the map the curve of the deeper and shallower parts of the Sound, to draw the lines for each fathom of depth up to 8 fathoms, and then for every two fathoms, that is for 10, 12, 14 and so on; and in addition, to make the lines for 7, 18 and 24 fathoms much heavier than the others; and to use differently colored inks for the lines 4 to 8 fathoms, 10 to 22, and 24 and beyond; or else give the areas 3 to 8 fathoms, 8 to 24, and over 24, different shades of color.

ings. For like all New England, the Sound received vast deposits of gravel and sand in the Champlain era from the depositions of the great glacier; and ever since these depositions were made, the rivers have been carrying in detritus, each year making its large contributions; the estimate, therefore, that the original surface, as it was before the Glacial era, had been covered by all these deposits to an average depth of 50 feet, cannot be excessive. After such a process tending to obliterate all depressions, especially over the northern half of the Sound which has received the most of the detritus, it is certainly obvious that better defined river channels than exist are not to be expected.

But the conclusion from the existing channels above suggested has at least three sources of doubt—*one* arising from the present action of tidal currents; a *second*, from outflowing under currents which occur at times in connection with large bays; and a *third*, from the configuration of the rocky basement beneath the mud and sand of the bottom of the Sound.

(1.) Jutting capes, especially if prolonged far out beneath the water, as well as obstructing shoals or reefs, inasmuch as they narrow the Sound, give increased velocity to the tidal currents passing by them. This cause is sufficient to account for the large deep holes—30 to 33 fathoms—opposite Norwalk, where "Eaton's Neck" on the Long Island side makes a long projection into the Sound beneath its waters, which projection at its extremity, three miles out (and hence nearly half across this part of the Sound), close along side of the deep holes, is within 6 fathoms of the surface. Again, near the "Middle Ground," south of the mouth of the Housatonic, or of Stratford, a large shoal but 2 feet deep in one part, there are deep holes both off its northern and southern extremities, the former of 20 to 21¼ fathoms, and the latter of 20 to 27½ fathoms; and they are in part at least an obvious consequence of the tidal currents sweeping by.

Ten miles west of the mouth of the Connecticut, the Sound commences to narrow toward its eastern termination, its southern side here bending up to the northeastward; moreover shoals made from Connecticut river detritus, contract the breadth on the north. Consequently, here begin two depressions, and half a dozen miles east, a third on the north, which three unite in one broad range of deeper water, 18 to 32 fathoms in depth, that continues eastward, and finally increases to 50 fathoms as the waters approach the channel, called "The Race," by which they leave the Sound and enter the Atlantic.

(2.) The *outflowing under-currents* of bays are produced, especially when the broad opening has a comparatively narrow principal channel with other passages, among or over reefs; and they are strongest when the waves and currents occasioned by a storm drive heavily toward and into the bay; and still more so if a river add its floods to the waters which the storm waves and currents pile up within the bay. I do not know of any observations about the bays on the Sound tending to show where such under-currents exist, or what in any particular bay is their force or direction; and we are at a loss as to the effects to be attributed to this cause.

(3.) The actual configuration of the rocky substratum of the great basin in which the waters of the Sound rest is also little understood. Long Island has no rocks at surface, or about its points; and the Sound east of Hurl Gate, except quite near its shores, is also without any projecting rocks. Some of the prominent sand-spits of the shores, as those of New Haven and Stratford Point, may be traced far southward by means of the soundings. But it is not always easy to decide whether they have resulted solely from the detritus of the rivers to the west of whose mouths they lie, or whether a rocky basement has determined the form of the projecting spits. On the sand-bed off the west point of New Haven harbor there are surfaces of bare rock, giving evidence of a rocky basement. Off Stratford Point, west of the mouth of the Housatonic, soundings have discovered no such rocks; and yet it is probable that the form of the bottom is here determined by the rocks underneath. On Eaton's Point the map says "rocky" at one spot; and the existence of this spit may also have been determined by the rocky basement below. But even when the spits or projecting sand-bars are proved to cover a ridge of rocks, it is not certain that this ridge may not have been a result of the excavations of the glacier, and of sub-glacier streams.

The shoals and deep holes in the vicinity of "Eaton's Neck" are directly south of the mouth of Norwalk river, and those about "Middle Ground" are south of the mouth of the Housatonic; and the question arises: Were they partly made by the rivers when the land was more elevated, or may they have been determined solely by the rocky configuration beneath and existing currents? It is apparent that without some direct investigations our conclusions can only be uncertain probabilities.

Yet notwithstanding all the doubts from the above mentioned sources, there are so many examples of depressions leading from the bays at the mouths of rivers over the bottom of the Sound, so many in

which the outflowing under-currents of bays appear to be insufficient to account for the facts, either because the bay is not of the shape to produce appreciably such an effect, or there is not in the currents the proper accordance with the ebb in direction, that we think the facts afford strong evidence in favor of a former elevation of the region—an elevation probably not less than 150 feet. In such a case Long Island would have been literally the southern border of New England, and the universal glacier would have had no great basin of salt water to span in order to reach what is now the Island, and deposit there the boulders of Connecticut rocks, some of which, according to Prof. Mather, are from 500 to 1000 tons in weight.*

* It is difficult to explain the facts in detail with regard to the Sound without a map at hand. The following observations on the subject are however here added.

The main course of deep water through the Sound west of the meridian of Guilford commences near the northern shore of the Sound, off Coscob harbor and Greenwich Cove, (near the boundary between Connecticut and New York), and just here enter Byram, Mianus and Turn rivers. From this region it stretches eastward, passes the north point of the Eaton Neck spit, leaves "Middle Ground" to the north (and consequently in this part is south of the middle of the Sound), and then continues directly eastward till it almost touches the north coast of Long Island (being less than a mile off) in the line of Guilford. At the very end of the deep water channel the depth is 18¾ fathoms; just east of it, the depth is only 11½, then 10 and 9 fathoms. But about 6½ miles a little to the north of east, about two from the shore of Long Island there is an oblong deep hole, 18 to 19 fathoms in depth; and 2½ miles beyond, in the same direction, commences the southern arm of the great central range of deep water which continues eastward out of the Sound. The great range of deep water, seventy miles long, that commences in the west near Greenwich, must, as already observed, owe something of its depth, in its eastern portion at least, to its distance from the northern shore of the Sound or the region of rivers and detritus; and, again, it may have had its course determined originally by an east-and-west depression in the configuration of the basement rocks of the Sound. Still it affords some reason for believing that it once contained the channel of a great river. It begins against the north shore near Greenwich, just where three streams enter the Sound, as if a continuation of their united channels. Its depth at its eastern extremity, and its abrupt termination there, are reasons for inferring that it once continued still farther east, and was probably kept open by a flow of water through it. If the land were formerly higher by 150 feet, as has been supposed, the required conditions would have existed for making it a river course. But the query comes up, where in that case would have been the discharge? Its abrupt eastern termination takes place right opposite the large and broad Peconic bay which divides the eastern end of Long Island for a distance of nearly 20 miles, making the Island in form like the profile of an alligator, with its long mouth (Peconic bay) wide open; and the interval of dry land between the Sound and this bay is hardly three miles wide. Moreover, directly in the line of the depression, the land is low, and is intersected by Matituck lake, and also by various channels on the Peconic side. These facts lead to the supposition that this Sound stream of the Glacial era, whose tributaries included

5. Events and Results of the Champlain era.

The Glacial era closed in a subsidence of the land over a large part of the continent, the initiatory event of the next or Champlain era.

1. *Amount of Subsidence.*—The amount of the subsidence about New Haven is uncertain, because the actual height of the land in the Glacial era is not yet satisfactorily determined. It was so great as to carry the land considerably below its present level, as evinced by the height of the New Haven plain, this plain having been made and leveled off in the waters of the era. Taking the level of this plain as marking the water level, we learn that about the College square and for some distance to the north, and either side of this region on the same east-and-west line, the depression was near 40 feet. Farther to the north it increased gradually to 70 feet and more in Hamden; while

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the Housatonic and other rivers to the west, may have discharged through an opening into Peconic bay. and that this opening was filled up by sands during the following era of submergence (the Champlain era), and cotemporaneously the adjoining southern portion of the Sound was made shallow by the same means. The form of the bottom in this part of the Sound favors the idea that the sands for filling it came from the direction of the Peconic bay.

But the existence of the oblong deep hole in the course of a direct line to the southern arm of the great eastern deep water region of the Sound hardly nine miles distant, brings up the enquiry whether the river channel may not after all have been over this route *within* the Sound. The submergence of the Champlain era would have afforded the same means as stated above for filling up with sands this part of the Sound and for stopping off abruptly not only the channel of the Sound river, but the great depression in which the channel lay; for the waves of that era must have swept across the land in one or more places from the Peconic bay into the Sound.

If this latter view is the right one, the great Sound river, commencing in the rivers of the vicinity of Greenwich and taking into itself the waters of other rivers eastward to the Housatonic, and still others from Long Island, would, after receiving the Housatonic, have derived little else directly from the north until reaching what is now the eastern deep-water region; and this it would enter by the southern arm of that region. The rivers of the New Haven coast and other small streams between it and Sachem's Head, would have taken an intermediate course over the Sound to the same meridian, and then entered the middle arm. The rivers from Guilford to Killingworth harbor would have flowed eastward to the commencement of the northern of the three arms. And then a few miles beyond this, the northern arm would have received the Connecticut river, the great tributary, and from this point all the fresh waters of the various rivers would have been combined in one grand flow on their way to the ocean. From the depth of water and the character of the *deep holes* over the deep-water region south of the Connecticut, it may be inferred that here was actually the great bay of the Sound river into which the ocean waves set as they do now into the mouth of the present Connecticut. The latter has its deep holes inside of its bar; for the depth within the channel of the present river at low tide is 6 to 7 fathoms, while there are but 10 feet of water over the bar.

to the south it diminished in height, being but 30 feet in the latitude of Halleck's place on the bay. The facts on this point are given beyond (p. 88). North of Connecticut, over New England, the amount of depression below the present level was still greater, and increasingly so with increase of latitude, it having been 200 to 250 feet at least in central New Hampshire, 400 about Lake Champlain, and 500 feet on the St. Lawrence.

2. *General consequences of the Subsidence.*—As the writer has remarked upon elsewhere, an immediate consequence of a subsidence of the land, and especially of one which was greatest as a general thing to the north, would have been the bringing on of a warmer climate, and thence, the commencement of melting in the glacier.

As another result we note that the slope of the great valley of the Connecticut would have become less than it is now. Consequently the motion of the Connecticut valley glacier would have been greatly retarded, if not rendered altogether null. Moreover the rivers would have had a diminished rate of flow, and would therefore have spread in wider floods than ever before, becoming in some parts a series of lakes; and the lakes also would have had an unwonted expansion. The great flow of waters from the melting ice would have immensely augmented the floods in all directions.

Such an extended change of climate over the glacier area was equivalent in effect to a transfer of the great glacier from a cold icy region to that of a temperate climate and melting sun. The melting would therefore have gone forward over vast surfaces at once, wide in latitude as well as longitude, and not merely along a southern edge with slow creeping progress northward. Hence, as another result, the depositions of sand, gravel and stones from the glacier, would have taken place almost simultaneously over regions scores of miles wide in latitude, and in general without special accumulations along a southern border like what is called the *terminal moraines* in the Alps. They would have descended alike over the hills, plains, and valleys, lake regions, flooded rivers and sea-shore bays; but not with like results over these various regions, for wherever there was water in motion beneath, the water would have worked over the pebbles and sand and produced some stratification of the material, or at least have leveled all off at top. Thus unstratified and stratified drift (the latter including the so-called modified drift, as well as a large part of the "alluvium" of river valleys) were formed simultaneously, and both in the Champlain era.

The *depositions* made directly from the glacier as a consequence

of its melting, and which belong to the opening part of the Champlain era may be first considered; and afterward the secondary and later results.

1. Events and results of the Opening Champlain era.

1. *Depositions over the hills.*—The deposits over the hills in the New Haven region, consist, like those of the rest of New England, of sand, stones, and large boulders, mingled pell-mell, or without stratification, except where they fell into lakes and rivers.

This unstratified drift is found wherever the land rises above the level of the stratified "alluvium" of the New Haven plain, except along the upland valleys. In some places it appears to be more or less stratified, as near the Seymour turnpike (running west from Westville) after passing the first hill (that of the Edgewood line); but in this and other similar cases the stratification is owing to the fact that the region in the time of the melting glacier was the course of a flooded stream. The boulders and stones are not to be looked upon as lying just where they were dropped in all cases, nor as being formerly in the same large numbers as now over given areas; for the sands and smaller stones that fell with the larger masses have to a great extent been washed away to lower levels, and carried off by streamlets to rivers, and by rivers seaward, and thus the large stones that crowd the surface in some regions may when first dropped, have been many feet apart, or even scores of feet away from the spot where they now lie.

The character of the stones and the size of the boulders over the hills show what is the nature of much of the material which fell into the waters, and which now lies over what was the bottom of the bay in the Glacial era.

The larger boulders of the New Haven region consist mostly of trap and sandstone; and next to these in size and numbers are those of gneiss and quartz. Those of trap, sandstone and gneiss are quite numerous over the western border of the region, especially along the eastern margin of the Woodbridge plateau; those of quartz rock have a very wide distribution. Only a few of gneiss have been observed as far east as Sachem's ridge.

Some of the largest of the trap boulders are as follows:

One 2½ m. north of Westville, on Boulder Hill, measuring along its diameters 29, 14 and 12 ft. and weighing at least 400 tons.

The boulder in pieces making the Judges' cave (the place of concealment of the *regicide* judges for a while in 1661), 1¾ m. east of south of the preceding, on the top of the West Rock ridge, the masses *when together having* weighed at least 1000 tons.

One on the Woodbridge heights, 1½ m. southwest, about 10 feet in its diameters, but now in halves.

One in the northern part of the Edgewood grounds, a mile southeast of the last, and 2 m. a little west of south from the Judges' cave, about 8 feet cube.

Three others, half a mile south of the last, in the same grounds, measuring 25, 18½ and 8½ feet, 14, 8½ and 7 feet, 8, 5 and 4 feet.

One near the Derby turnpike, ½ m. E. of S. of the last, of 14, 6 and 5 feet in its diameters.

One in the woods north of the Stoeckel farm, ½ m. S.W. of the last, and in the same line nearly with the Judges' cave and the Edgewood boulders.

On the Milford turnpike nearly a mile east of south of the latter, ¾ m. west from Allingtown, measuring 15, 8 and 5 feet.

One at Savin Rock, farther south, 8, 6 and 4 feet.

These masses are all on the *western* border of the New Haven region. The height given in each case is the height above ground, the depth to which the boulder extends below the surface being uncertain. Many of those that formerly lay over these heights have been broken up for use in house-building.

Over the same region sandstone boulders are numerous, but they are seldom very large, owing to the nature of the rock. One of tabular form on Boulder Hill measures 21, 15 and 5 feet.

There are also large trap boulders more to the eastward. One on Sachem's ridge measures 16 feet in length and 8½ in greatest breadth; and one in East Haven, back of Mr. Woodward's, of 11, 9 and 6 feet.

There are also occasional masses of native copper derived from the copper mines of the Connecticut trap and sandstone region. A mass from the vicinity of East Rock, given to the Yale Cabinet by Mr. Eli W. Blake is probably of this kind. Another weighing 90 lbs. was found early in the century on the Hamden Hills.

2. *Depositions over the waters.*—The New Haven bay in the Champlain era covered the whole breadth of the New Haven region, from the Woodbridge range on the west to the sandstone ridges of East Haven and North Haven on the east, and spread northward into Hamden. East and West Rocks, Pine Rock and Mill Rock were cliffs within its area, or on its borders. Sachem's ridge was a long north-and-south peninsula south of Mill rock: and the Beaver Hills, another south of Pine Rock. The Beaver Pond region was, for a while at least, the deep central portion of the New Haven bay; it lay in the interval between Mill Rock and Sachem's Ridge on one side, and Pine

Rock and the Beaver Hills on the other, close alongside of the latter. Mill River entered a narrow arm of the bay between East Rock and Sachem's ridge, and the waves widened its head and battered Mill Rock for some distance west of Whitneyville. This Mill River arm was encumbered by two or three low sandstone islands, the northernmost of which is now the site of the residence of Stephen Whitney. West River opened into another arm which lay between the eastern of the Woodbridge heights (or the Edgewood range of hills) and the Beaver Hills, and West Rock Cliff and Pine Rock overlooked it on the north. Up the Quinnipiac valley, beyond East Rock, stretched a long and broad arm of the bay, which was the great inner harbor.

We come now to the consideration of the action of the waters of the bay in arranging the material dropped into them by the melting glacier. The large boulders were evidently the first to fall; for none were found on the plain when it was first taken possession of by the colonists, although such masses were then very numerous over the low Beaver Hills and Sachem's ridge, and are somewhat so still notwithstanding man's free use of them. Further, in no excavations into the alluvium of the plain for cellars, wells, or other purposes, (as we are informed by Messrs. Perkins & Chatfield, Mr. Isaac Thomson and Mr. D. W. Buckingham, who have superintended such work for years past) have *boulders* anywhere been found, with only two exceptions; and these are really no exceptions, since the boulders in each case lay on the foot slopes of sandstone ridges. One occurred at a depth of 10 feet beneath the gravel of the alluvium, and was found while making a pit in Trumbull St., near the house of Prof. Fisher; it was of trap and about two feet across. In the other case a number of large stones were met with in digging a well on Whalley Avenue near Blake Street; Mr. Buckingham, who reported the fact to me, attributes their occurrence there to the nearness of the place to the Beaver Hills.

As the melting went forward, the sand, pebbles and cobble stones were thrown down together; but they underwent as they fell an arrangement which varied according to the movements in the waters beneath. The bay had its tidal currents, as now; its areas of comparatively still waters; and besides, certain channels along which the flow of the rivers increased greatly the force of the ebbing tide. The stratification of the deposits varied accordingly. Where the currents were strong, they washed away the sand from the stones, or if very strong, the sand and smaller pebbles, and thus layers of coarse gravel were made—gravel beds being always deposits from which the sand has been sifted out by moving or flowing water. Along the main river courses there ought to be found, consequently, long *gravel courses*,

marking the direction of the strongest currents, and these gravel courses should be not far below the surface unless the depth of water in which they were deposited were too great for this. Accordingly, we find that the valley of West River, near West Rock is a pebbly and stony region.

Another more remarkable gravel course extends from the head of the harbor between Meadow and Franklin streets over State and Orange streets, toward and beyond Whitneyville, and this was evidently the course of the *Mill River channel.* It follows (see map) the west side of Mill River from Whitneyville down to Grand street, then diverges a little westward, the region between Mill River and Franklin Street, as I am informed by Mr. Chatfield, being less stoney than that to the west. Franklin street is about 500 yards from the river. At Neck Bridge, below the East Rock range, the "alluvium" on the *west* side of Mill River is four-fifths stones; and on the *east* it is very pebbly, but the proportion of stones to sand is not more than 1½ to 5; and farther east the proportion of pebbles becomes quite small. The gravel is in all parts exceedingly coarse, and consists largely of cobble stones. This gravel course extends far up Mill River, and is as coarse in its stones near Ives' Station 4½ miles to the north, as it is over the New Haven region. Just south of the Mt. Carmel gap, the stoney character is still more remarkable.

Another gravel course, but coalescent with the preceding as it approaches the bay, passes northward along the Canal railroad to the *west* of Sachem's ridge (*Sm*), instead of to the east of it. It has the course of the *East Creek* valley. The pebbley deposits or gravel underlie the surface from the head of the bay, northward across State street; its western border follows approximately (as I learn from Messrs. Perkins & Chatfield) a line along State street to Crown, across from this point to the corner of Chapel and Church; along Church from the corner of Church and Wall to the corner of Grove and Temple; and thence along the east side of the cemetery.

The extent of the region shows that the flow producing it had the breadth and character of a tidal flow. This East Creek *tidal channel* was connected directly with the central interior basin of the harbor, the Beaver Pond depression, as the channels in the surface along Webster and Munson Streets demonstrate (p. 53, 54).

The Mill River and East Creek tidal courses were branches of the great central tidal flow up the bay.

The gravel-course of the Quinnipiac is not in sight. This inner harbor of the bay was deep, and swallowed a vast amount of great stones, *gravel and sand,* without being filled to the surface.

The courses of the tidal currents of the bay are also apparent in the less height of the drift formation wherever they swept along. Thus, within the range of the Mill River tidal course, at Neck Bridge, the height of the terrace on the *west* side of the river is but 32 feet, while it is 42 feet on the *east* side. This Mill River tidal current, although strongest, perhaps, to the west of Franklin street, had a wide spread to the eastward. For the area over which the terrace formation is below its normal height includes not only a region west of Franklin street, but all east of it to the river, and even a large part of Grape Vine Point (the wide point of land between Mill River and the Quinnipiac). Near the bridge at the foot of Chapel street on this Point the height of the drift or terrace formation is only 12 feet, and between this and the southern extremity of the Point, it is still less; half across the Point in the same line, it is only 21 feet: and half a mile to the north, near the Barnesville or Grand street bridge (the second bridge over Mill River), the height is only 29 feet. On the Quinnipiac side of Grape Vine Point, on the contrary, the plain has its full height, being 34 feet in the same east-and-west line with the Chapel street bridge, and 40 feet in that with the Grand street bridge. It is evident therefore that the central part of the great tidal wave up the bay in the Champlain era swept northward between Meadow street on the west and Ferry street in Fair Haven (on Grape Vine Point) on the east, an area over 1½ miles wide; that it continued to be felt on the east side of the river to the north of Barnesville bridge; but at Neck bridge, approaching the south point of the East Rock range, it was pushed more to the *westward*, the terrace on the *east* bank at this point having a height of 42 feet, or the full normal elevation. An *eastern* branch of the tidal wave entered the Quinnipiac basin through the broad channel which forms the lower part of this river. Owing to the bend to the westward in the lower part of this channel, the wave was thrown against the *eastern* shore, so that the terrace formation on that side is mostly wanting while built up nearly to its full height apparently on the western side of the channel even quite to its mouth.

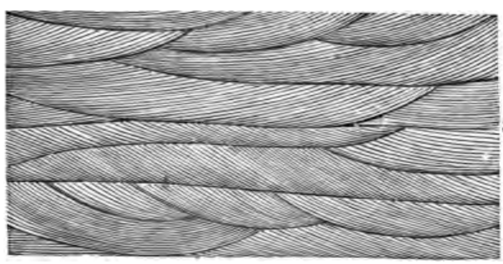
By closely studying the nature of the stratification of these deposits beneath the New Haven plain, the particular character of the action of the waters may generally be made out, even, in some cases, to distinguishing the effects of individual waves and changes in the action of tidal or river currents. A good example of this is afforded in the region south of the East Rock range (or of Snake Rock, its southern termination) between Mill River and the Quinnipiac, where sections of the deposits have been made in grading for the Hartford and Air-Line

railroads (see the course of these railroads between Mill River and the Quinnipiac on the map). The whole height of the alluvium above mean tide is in this region from 42 to 45 feet. The cut through it for the railroads extends nearly southwest and northeast, and is about two-thirds of a mile, or 1200 yards, long. After the first 700 yards, the railroads pass under a bridge, and just beyond, the separate cut for the Air-Line railroad commences. The depth of the section is about 16 feet at its Mill River end, 20 at the bridge, and 26 toward the upper or Quinnipiac end. A number of interesting facts are to be observed in the sections:

a. The diminution in the proportion of pebbles on passing east from the Mill River valley is well seen. Along the Air-Line road they constitute hardly a fifteenth of the whole mass, although in an occasional small layer they are of large size, even like cobble stones.

Toward the more northern or Quinnipiac end of the cut, the layers are not only less pebbly but the lower part of the section contains two to four irregular layers of exceedingly fine clayey sand (M, fig. 2). The material adheres rather firmly, holds water well, and is so damp at all times that the exposed surface has in part become green from a covering of moss. The clayey layers are separated by others of sand, and an occasional one of pebbles.

1.



b. The alluvium is in nearly horizontal layers, just as it was originally laid down. But these layers are quite irregular, often of small lateral extent, and where composed of sand are very commonly made up of wave-like parts, from two to many yards long, as in the annexed figure—which represents a part of the surface six feet in height, about half way from top to bottom in the Air-line railroad cut.

c. A marked variation from horizontality occurs at the northern or Quinnipiac end of the cut, where the layers, as shown very distinctly in the firmer beds of clayey sand (fig. 2), dip downward four feet in a length of 30 feet, or from $7\frac{1}{2}$ to $3\frac{1}{2}$ feet above the railroad. This dip is toward the Quinnipiac river, or toward the old harbor, and may *have some relation to* the original bottom of the basin.

d. The sand of the sandy layers is *obliquely laminated* (not an uncommon fact in such deposits), as shown in the above figure. This division into thin oblique layers is not apparent when a cut is first made through it with the spade, but appears often on a surface of natural fracture, and very distinctly after exposure for a while to the winds. It shows that the sands were deposited in these delicate oblique layers while they were being accummulated in the long or horizontal beds which consist of these.

e. Throughout the upper part of the section, (above the line N S fig. 1), the inclination in the oblique lamination is mostly to the northward: while in the lower part (below N S) it is as generally to the southward. Layers containing both slopes may be observed in each, but the above are the prevalent courses. The formation is thus made up of an *upper* and *lower* division; and in many parts the two are separated by a thin band of large and small pebbles. Near the junction of the Air-line and Hartford tracks, the dividing plain is but two feet above the level of the railroad; to the eastward it retains nearly the same level (about 22 feet above meantide), but it is higher above the track, there being here a descending grade in the road. Below this bridge, or toward Mill river, the upper division is the only one in sight; the level of the dividing plain passes beneath the surface of the railroad excavation, and for this reason cannot be traced. For the first two hundred yards on the way toward Mill river, the slope of the oblique lamination rises quite uniformly to the southward as in the *upper* division above the bridge; through the next one hundred yards, this is still the prevalent direction; but farther toward the Mill river end of the cut both slopes occur, and that of the *lower* division finally becomes the most common.

f. In the upper part, the sands, through the cut for the Air-line road, have the ordinary dirt-brown color; in the lower part they are *brownish-red.* Thus there is a marked distinction between the two divisions in *color*, as well as in lamination. This color is of course not observable in the pebbly layers. It is owing mostly to the fact that the grains of quartz are tinged outside by red oxyd of iron, like those of the red sandstone.

The following conclusions flow from the facts here noted.

(1.) It has already been observed that Mill river valley, especially its west side, was the course of a powerful tidal current which set in and out over what is the head of the present harbor, whose ebb was increased by the flow of the river. From the diminution in the amount of pebbles to the eastward of the river (§ *a*), it appears that the tidal

flow, as it spread in that direction around what was Snake Rock headland, rapidly lost its force; and finally, when fairly in the Quinnipiac basin, as the beds of fine clayey sand show, there were intervals of comparative quiet or of only gentle movements. The fact of these gentle movements is proved not merely by the fineness of these beds, but also by a very delicate contorted lamination in them, which in some places looks as if due to the smallest of eddyings in the water at the time of deposition; and also by successions of obliquely-laminated layers of sand only one or two inches thick, constituting here and there an overlying bed. Where layers of stones, or thick obliquely-laminated sand-beds, exist between these clayey beds, they indicate that a time of rougher movements intervened.

(2.) Since the slope in the oblique lamination throughout the *lower* division of the alluvium dips to the southward, or rises to the northward (§ *e*), the deposition of these beds took place under the action of a tidal current flowing northward, that is, *into* the old Quinnipiac harbor; and the reverse direction of the lamination in the *upper* division implies a current during its formation to the southward, *away from* the old harbor, or *toward the present bay.*

Such a change of current (A) would have attended the flow and ebb of each tide. But this cause of the transition in the beds would make the whole deposition a twelve-hour operation; which, even with a melting glacier above to supply material, would have been incredibly quick work. It might (B) have proceeded from a change in the place of discharge of the Quinnipiac waters, such as would have added the river current to the ebbing tide. But there is no evidence in favor of this in the existence of an old channel, and much against it, in the character of the layers along the present channel north of Fair Haven. It might (C) have resulted from the setting in of an extraordinary river flood, giving great force and volume to the outflowing tide, and not only along the proper channel of the stream, but far and wide over the low lands adjoining. Through such means the action of the incoming tide would have been as much weakened as that of the ebb enhanced; and, as a consequence, the oblique lamination of the sands would have been produced by the *outflowing* flood. The special influence of the Quinnipiac flood would have diminished westward, where finally it would have encountered a similar, though smaller, Mill river flood; and hence it is natural that the alluvium should here lose its Quinnipiac characteristic and take that of the other stream, as stated in the closing part of (§ *e*). It might (D), if a flood were in progress, have been due to the fact that the

depositions had reached such a level as to impede the inflowing tide, and thereby give the ascendancy to the river current; this being favored by the height of the land at the time.

Of the causes suggested above for the difference between the lower and upper divisions in the sections, C and D are the only ones that can be entertained; and such a flood would have been sooner or later a natural consequence of the melting of the glácier in progress. It would have been a flood enormous in extent and vast in effects; it may have been not merely an overflow of a few months, but of a period of years.

(3.) The subdivisions of the layers into subordinate wave-like parts may have resulted from the plunge of the waves that accompanied the tidal or current movements of the waters. Each of these subordinate parts is not the whole that was formed by the plunge and flow of a wave, but this *minus* what it lost by the succeeding plunge or plunges—as a little study of figure 1 will make apparent. In these wave-like parts of a bed, the oblique layers usually diverge as they rise upward, as shown in figure 1. The wave struck at the end from which the lines diverge, and as it pushed forward with slackening force, it dropped more and more of the the sands taken up, and so the little layers formed by it were made gradually thicker. So much material deposited with one fling of a wave would seem to indicate rapid work in the deposition of the beds.

The reasons for regarding these and other like beds as depositions directly from the glacier are the following. (1.) Stratified deposits were thus made by the glacier and the waters beneath somewhere about the New Haven region; and no others exist that can be such. (2.) These beds, consisting largely of interstratified sand and gravel, and in part of layers of cobble stones, have characters according precisely with the supposed mode of origin. It will be noticed that the layers of cobble stones have not required for their formation, on this view, streams of tremendous magnitude and violence, beyond all physical probability, in order to transport the stones from their place of origin, 50 or 100 miles or more to the north; the work of transportation was done quietly by the glacier, and they were simply dropped to their places; much more moderate streams served to sift out the finer material so as to leave the larger stones alone. (3.) These sand and gravel beds could not have been formed like ordinary sand-banks on a sea-shore or in a bay. For the waves and currents, which are the means of piling up such banks, could not have introduced the layers of gravel or cobble stones except they had been furnished by *some other agency;* and the amount of sand that the waves move in

a stroke is but little, and this is spread widely. (4.) Again, they could not have been formed as sea-beach deposits. They have not the structure of such deposits. Moreover, if the beds of the New Haven plain had been produced by the gradual growth of a beach seaward, the harbor would have also existed somewhere, in narrow areas at least, among the encroaching beaches, and remains of the cotemporaneous mud-flats of the harbor should occur to mark its position. But no such clay or mud deposits have in fact any where been found, except in the Quinnipiac valley (upon which we remark beyond); none along the courses of Mill and West rivers, where we should naturally look for clayey interpolations among the sands, if not thick beds. The work of filling up the bay was evidently too rapidly done for the accumulation of mud or clay from the contributions of rivers.

3. *Filling of depressions with the drift.*—The depositions from the glacier filled up the greater part of the New Haven bay nearly or quite to the sea limit, as is shown by the even surface of the plain, the whole having been leveled off by the waters. The rivers, where not too deep to be filled, had currents to sweep out the sand and keep them clear.

The Beaver Pond depression, the great central basin of the bay, was one of the unfilled channels; and unfilled, in all probability, because of its depth. The drift was dropped over it as over the rest of the bay; but its depth saved it from obliteration; it still remained the open central basin of the bay. Its original communication with the wider outer portion of the bay was probably, as has been shown (p. 53), through the *West Creek* channel, whose extent, north-and-south course, and approximate conformity in direction and line with the Beaver Pond basin, accord with this view. During the melting of the glacier there would have been an abundant flow of waters from the northward through it; and these currents, together with the inward setting of the tidal flow, would have made the steep terrace-slopes that form its boundary, and those also of West Creek valley, which resemble in all respects the terrace-slopes along the rivers.

But while not filled by the depositing drift, the Beaver Pond depression appears to have lost much in breadth; for in the surface of the adjoining plain, especially along Crescent street, there are several large isolated basin-like depressions—deep holes, as they are often called, although sometimes 100 yards or more across—which must have been cut off by the depositions made by the glacier. The east and west Goffe street ponds occupy such exscinded depressions. The

valley of West Creek appears to have been dissevered from the Beaver Pond basin by the same means; having no river (p. 52) to perform the office of sweeper, it would have been unable to resist the encroaching sands.

But while the Beaver Pond depression was thus closed in the direction of *West* Creek, a tidal communication appears to have been kept open between it and the deep parts of the bay, through the wide valley-like depressions near Webster and Munson streets, and thence through *East* Creek. The gently sloping sides of the East Creek valley along the course of Chapel and Elm streets below Temple, as well as near Webster and Munson streets, and other facts already mentioned (p. 54) correspond with the view, as just stated, that this channel was originally a depression in the sandy bottom made by the sweep of the tides. Accepting these views, the channels of East and West Creeks, which diverge at the bay, make together the circuit of the original New Haven square, and converge toward the southern extremity of the Beaver Pond depression, were both, though at different times, outlets of this great central basin.

The valley of Pine-Marsh Creek was another of the deeper glacier excavations, as already explained; and one too deep to be filled with the droppings of the glacier. This is proved by the remarkable breadth of the valley, and the fact that it is bordered by a steep terrace-slope, although no large stream but that made by the melting of the glacier ever flowed through it. There are deep holes or basins in the plain along its borders which may be explained in the same way as those adjoining the Beaver Pond depression; that is, they are spots that were unfilled by the sand and gravel of the glacier, because of their depth.

The Quinnipiac valley was far the largest and deepest of the deep basins of the New Haven bay; for while in one part a mile in width, the terraces on its eastern and western sides are very narrow. Moreover they are mostly below the usual height; and in some places so poorly defined as to be apparently altogether wanting. But to the south, between the basin and the bay, there is a great development of the drift or terrace formation, indicating that over this wide area the material was dropped by the glacier in shallow water. Red sandstone, the basement rock, outcrops from beneath the sands of the formation south of East Rock and in Fair Haven, opposite borders of the plain. The fact that the tidal flow in the bay during the Champlain era was not over this area but either side of it (along Mill River and the Quinnipiac channel), is other proof that the region was *originally* shallow; for the course of the tidal wave is along the deeper parts of a bay.

In contrast with the basin, the Quinnipiac valley near the village of North Haven and north of it has its lower flats exceedingly narrow and the upper plain of great extent; and here, concordantly, the red sandstone is but a little way beneath the surface, for it outcrops along the river, and, as I am informed by Mr. D. H. Pierpont, is the bottom of all wells in the village. But the poor condition of the terraces in the Quinnipiac basin cannot be attributed solely to its extent and depth; it must be owing partly to the currents that swept through the basin in the era of the melting glacier; for the upper plain or terrace, evidently for the same cause, has in general been left remarkably low, often not half its normal height, about North Haven and to the north. It is to be noted also that the drift formation or plain south of the basin may owe something of its extent and height to the diminished velocity which the waters would have had after passing East Rock, as they there escaped the bounds of the Quinnipiac valley, and were free to spread widely to the westward.

4. *Origin of the material of the drift.*—The sand, gravel and stones of the drift-deposit of the plain came largely from the Red sandstone formation; (1) the pulverized sandstone affording sand; (2) the associated conglomerate yielding pebbles and stones; (3) the wear of fragments from the harder varieties of sandstone and conglomerate making other stones or pebbles. There are some pebbles of trap, but they are very few in comparison with what the preceding source supplied. The rest came from the region of crystalline rocks to the northwest and northeast.

The great trap boulders may have been derived from any of the trap mountains to the north. Those of the western border of the New Haven region, which are often tabular in form and sometimes thick-laminated in structure, were probably carried off from the heights between the western of the Hanging Hills of Meriden and Mt. Tom, though possibly in part from the West Rock ridge more to the south. The great fallen masses in some of the valleys of the Meriden mountains resemble many of these boulders in form, in fine-grained texture, and in laminated or jointed structure. The masses of the Judges' Cave are probably from these more northern trap ridges which, as already mentioned, are the highest of the valley. This view of their origin accords with the fact that the gneiss boulders so common along with them are probably from the adjoining region of the town of Granby, or from Massachusetts, farther north, as stated by Percival after a comparison of the rocks. The quartz and quartzite boulders may be from the adjoining region in Massachusetts. But they are

widely spread over the New Haven region, and they may have come from Vermont or New Hampshire, where such rocks occur.*

5. *Rapidity of deposition.*—The wasting of the glacier, beginning as the warm Champlain era opened, (p. 66) would at first have been slow, and mainly above. But after a while, the glacier would have been reduced to a comparatively thin sheet of ice, and then, through the heat conveyed into it in all directions by means of waters from above, and that received through flowing waters and air below, the rotting of the mass would have become general, and the unloading of the glacier would have gone rapidly forward. The period of years occupied by the deposition of the sand and boulders may therefore have been short. It may be queried, considering how much appears to have been done by a single wave, whether one year, or even less, would not have sufficed for the *upper* division, or the upper twenty feet, in the part of the formation represented in figure 1, on page 73.

With so quick a way of dumping the load of the great glacier it is nothing incredible that the channel of West Creek should have been cut off from its northern continuation, the Beaver Pond basin; nor is it impossible that, by like means, Mill River should have had its course through the same basin and channel intercepted by half a mile of sand and gravel, and have been forced to open a new way for itself by Whitneyville, although deemed improbable for the reasons stated on page 55. Even the floods of Niagara were thus stopped short; the old gorge, as long since made known, was filled to the brim for miles by the drift, and the river was turned off to work out another passage through the rocks.† The accumulations of a "ter-

* Besides the boulders described on page 68, there are the following in more remote localities. One, of trap, 6 miles in an air-line north of the city, 1¼ m. west of Ives' Station, fifty rods west of W. Fenn's, south and east of a bend in the road, is 88 feet in girt and 17 feet high, and must weigh over 600 tons. Less than half a mile south of this spot, near, and east of, the "West Woods" road, a little south of R. Warner's house, there are four great trap boulders, nearly in a north-and-south line, the largest 50 feet in circuit. Half a mile north of the Mt. Carmel gap, a short distance west of the railroad track, (and in full sight from the cars when passing), there is a boulder of trap, somewhat house-like in shape, which is 25 feet long by 14 wide and 16 high, with a girt of 68 feet; and along side lies a slice from its broad face, averaging 4 feet in thickness, which when a part of the mass, would have made its diameters 25, 18 and 16 feet, and its original weight at least 450 tons. It shows traces of vertical lamination, like a trap dike, and was probably taken off from some trap-mountain before it had fallen from its place.

† Dr. Newberry in his memoir on Surface Geology, already referred to (p. 49), mentions the Ohio river as another that was diverted by the filling up of the old channel

minal moraine" in the ordinary slow way would never have stopped the course of a Niagara. But before a sudden down-throw of sand and gravel from a freighted glacier, no stream is too large or rapid to hold its place.

Although the accumulation of freight by the old glacier must have required a very long period, even that of the whole Glacial era, the deposition of a large part of the older "alluvium," if the above view is right, was a rapid work—much more rapid than has hitherto been suspected. Any attempt to measure the interval of time between the depositing of the top and bottom layers by comparing the thickness of the formation at New Haven with the accumulations now going forward along the shores would lead only to great error. This conclusion holds not merely with reference to all similar formations made by direct deposition from the glacier, but also to others accumulated by the action of moving or running waters immediately afterward, inas-

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in the Champlain era, and states that its present course along the falls or rapids near Louisville was thus determined. Other cases also are referred to.

It is possible that in Mill River we find an example of such a change of course, as I have stated above. But the facts with regard to the Mill River gravel-course (p. 71) are another argument against it. It will be understood that this gravel is not that of the bed of the stream, but the material of the terrace or drift formation standing high along the border of the river; and that it is similar in character above and below the Whitneyville dam. It seems to be good evidence that the river occupied its present channel throughout the period of the deposition of the drift.

A change of course in the Quinnipiac through the cause alluded to is quite probable. The river at the bridge flows in a sandstone trough. the rock rising above the river 10 feet on the western side and over 20 on the eastern. Along the road running thence eastward to the depot (50 to 60 rods distant) which rises from 15 to 25 feet in level, there is no sandstone, and instead a deep bed of the sand of the stratified drift. The wells at three of the houses west of the depot go down 2 to 4 feet below high-water mark in the river, without reaching the "red rock." Moreover the low flats of the river north of the bridge spread eastward and sweep around to within 40 yards of the depot; and in consequence, a brick house recently built opposite the depot (across the street), while it stands in front on the firm sands, rests its northern or back walls on piles which were driven down in the meadows 20 feet without finding for all of them a firm footing. That the river's bed was once here is the supposition of those on the spot who know the facts. But we may suspect further, that the river from this point flowed southward to join the present channel half a mile below, the low level of the bottom of sandstone over this region determining it; and that the sands and gravel derived directly from the glacier or indirectly through the river floods, during the submergence (45 to 50 feet in amount, as shown beyond) of the Champlain era, filled up the earlier channel, so that the stream, when the land was afterward elevated, was forced to open a new channel, in doing which it took a course over the rocks because compelled to it by the existing slope of the surface.

much as the hills and valleys were everywhere left by the glacier loaded with sand and gravel ready and convenient for transportation.

The evidences of rapid deposition are so many and obvious that they appear to set aside any theory of the glacial cold which demands a slow decline of the era.

2. Later events and results of the Champlain era.

1. *Continuation of the Drift formation.*—It has been stated that, during the progress of the depositions by the melting glacier in the bay, the lighter or finer portions would have been largely sifted out by the moving waters; and while part of the sands would have been eddied off to one side, a much larger part would have gone with the current and the ebbing tide down the bay to be distributed by the tides chiefly *at their influx* along its borders.

Over the whole of the wide western portion of the New Haven plain, and especially the southwestern, the terrace formation consists of sands. To the north, toward Westville, at the entrance to West River valley, there are pebbly layers; but, on passing southward, these rapidly lose most of their pebbly character, and increase in fineness; and between Congress Avenue and Oyster Point, the beds are almost solely sand. The detritus which is *now* borne by the rivers to the bay is distributed largely along its western side, and there, consequently, are the great sand flats; and this is so because the direction of the tidal current in the Sound on its influx is *to the west*, and as it enters the bay to the northwest; and the depositions of detritus take place mainly during the inflowing tide. The same would have been the action of the currents and tides in the Champlain era; and hence this western part of the New Haven region would have been, from the beginning of the depositions, an area of accumulating *sand* beds.

The part of these sand beds that were made during the progress of the melting, should be marked off, if they could be distinguished, as belonging to the first section of the Champlain era, and only the subsequent additions, as "later results;" but the progress of the beds through the two intervals was continuous, and it is probably impossible to ascertain the limit between them. The hills and valleys, after the melting was completed, would in many places have been left thickly covered with sand and gravel ready for transportation by every little rill the rains might make, and the rivers would for a considerable time have continued to transport an unwonted amount of sand. The depositions along the borders of the bay for a while would, therefore, *have gone forward* with a rapidity almost equalling that of the melt-

ing period itself; and the decrease of rate would have been quite gradual. On the west side of the bay near Halleck's place (where the present railroad grounds abut against it), a section of the terrace formation 25 feet in height (the upper twenty-five) is exposed to view, and throughout it, the beds have precisely the structure exhibited in fig. 1 (p. 73), and differ only in the paucity of pebbles; they evince the same free supply of material and rapid deposition under the action of the waves. Moreover, the slope of the oblique lamination is toward the south (as in the lower part of fig. 1), showing that the deposition was accomplished mainly during the *inflowing* tides.

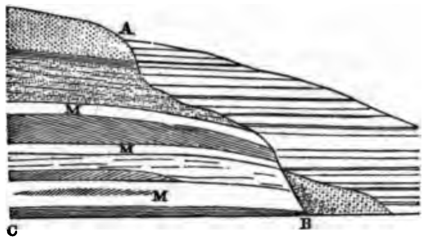
The result of all this transportation and deposition was an extension southward of the sand beds, as well as an increase in their height; and the terrace formation was thus completed to its outer limit. The plain stretching south to Oyster Point and over West Haven gives us some idea of its extension in that direction; but not necessarily its original extent, since the sea may have washed away much from its borders as well as from its upper surface.

Over the region toward Oyster Point, the beds are sandy throughout, and free from any upper layer of fine river or bay detritus, such as is deposited about existing mud-flats and sand-banks. On Grape Vine Point, between the mouths of Mill River and the Quinnipiac, there is the same absence of any thing like a layer of harbor mud over the sandy beds of the drift formation. The proof appears hence to be quite positive that *these sandy beds did not lie for a long period beneath the water, after the material was deposited.*

2. *Sand-formations on the borders of the Quinnipiac valley.*—The Quinnipiac valley was the site of the *inner harbor* of the bay, during the Champlain era—and a harbor of great extent and depth, as already stated. While the sand-formation was in progress down the bay, changes should have been going forward within its area. On its borders we naturally look for sand beds distinguishable from those that were made during the hurrying time of the melting by unconformability, and also by freedom from layers of coarse pebbles and cobble stones. One locality of such sand beds of considerable extent occurs on what was the southwestern border of the old harbor, at the northeastern end of the cut made through the terrace formation for the Airline railroad, south of the East Rock range. The character of the terrace formation along this cut has been described on pages 73, 74. The position and general character of these whitish sand beds are shown in the following cut. The part A B C is the terrace formation, consisting of beds of sand, some quite coarse pebbly, and below including

three layers (M) which are of clayey sand. A B is the plane of separation between this part and the layers of whitish sand. The latter

2



differ not only in their white color, but also in the absence of all pebbles, and in the much greater fineness of the sands. Through the washing of the waters against the shores, they were not only ground up, but they also lost almost entirely the oxyd of iron that tinges the quartz grains of the proper terrace formation. At the foot of the slope A B there is a collection of pebbles or stones, and for a short distance east of B, reddish sands; the pebbles and sand evidently fell down the bank from the layers above, when it existed as an exposed slope before the beds of whitish sand were deposited. These sands, moreover, were laid down in even layers, free from the oblique lamination that occurs in the terrace formation.

3. *Mud-formations in the Quinnipiac harbor.*—Besides these shore formations, the old harbor had its mud beds. They are the clay beds situated along the borders of the present river flats or meadows under 3 or 4 feet or less of sand: in these later times they have become the sites of numerous brick-yards. The clay beds vary in depth from 6 or 8 feet to over 25, the bottom in some places not having been reached at the latter level. Where penetrated they are found to rest on sand. The clay is very thinly and evenly laminated. The beds have been opened at several points near the outer borders of the meadows, on both their eastern and western sides, through a length on each of about three miles. The width of the border of clay is reported to be from 100 yards to a third of a mile. The two ranges converge toward North Haven, where the harbor had its head, and where, moreover, the terrace formation becomes wider and crowds upon the river. The clay continues north, between layers of sand, under the lower part of the village of North Haven. I learn from Mr. D. H. Pierpont, that in digging a well in the village of North Haven, after passing through 7½ feet of sand, a bed of clay 4 feet thick was met with, the bottom of which was 8½ feet above the level

of the Quinnipiac river. This 8½ feet was made up of fine quicksand. The clay was a sandy clay, or what the brick-makers call "weak clay." This well is about 80 rods east of the depot. At two others, between the depot and the river, clay was found, and in one, there was at top 4 feet of sand; then 5 feet of "weak clay;" and below quick-sand, 3 feet of it above the level of high-water in the river.

The clay beds, according to Mr. I. L. Stiles, do not extend beneath the deep muck of the great meadows; on reaching the muck, instead of keeping at the same level, it *dips downward* with a rather large angle beneath the muck. What lies beneath the muck, whether clay or sand, has not been ascertained. In making the track for the Air-line railroad, which runs for nearly a mile and a half obliquely (north-eastwardly) across the flats, piles were driven to various depths, down to forty feet; solid bottom was reached, but the nature of its material is unknown.

Over the region north of North Haven village, the upper plain or terrace is very wide and the lower relatively narrow, the reverse of what is true to the south. Moreover, the country is remarkably sandy, large fields of loose moving sands making part of the surface. These sands are the present top of the upper plain or terrace. When this region, in the Champlain era, lay at the head of the great Quinnipiac harbor near high tide level, it was in a condition to be washed over by the running waters, and it is probable that the grinding and sifting then went on that robbed the sands of their feldspathic and other softer grains; and that what the sands lost the harbor received as a contribution to the mud of the harbor, now the clay beds.

The description of these beds of clay is here inserted under the head of the "Later events of the Champlain era." But it is not at present possible to decide whether part, or even all, of the deposition may not belong to the early part of the era. We need to know something more definitely with regard to the relative positions of these beds and the others of the drift-formation before a positive conclusion can be arrived at. The layers of sandy clay in the section at the cut for the Air-line railroad, represented in fig. 2 (p. 83), although 20 feet above the level of the meadows, may have some relation to the clay beds farther north. The fact that they have a dip toward the Quinnipiac basin is a significant one, as intimated on page 72.

What depositions were going forward at this time in the Beaver Pond basin, the central basin of the New Haven harbor, cannot be ascertained without an artesian boring. Such a boring would develop several facts of interest; for the depth to the sandstone bot-

tom would give the depth of the original excavation; that of the beds of sand over it, the thickness of the drift derived from the glacier; that of any clay bed, or infusorial bed, or shell deposits, and of the peat, other important points in its history. The depth of the basin was small compared with that of the Quinnipiac harbor, as is evident from the present level of its meadows.

4. *Denudation.*—In this era of submergence, the sea breaking against the foot of East Rock and the other cliffs of the bay, must have worn away the sandstone along the base, and thus carried forward the degradation of the trap dikes and sandstone hills which had been begun by the glaciers. The waves acted upon the region in front of Pine Rock both from the direction of the Beaver Pond basin, and that of the broad West River channel. The part of the Beaver Hills occupying this position being thus attacked on both sides would have been soon swept away and a free passage made across for the waters. This spot is now occupied by a portion of the New Haven plain, directly proving that waters communicated across from the Beaver Pond basin to the West River channel, or the reverse, as just stated; and the degraded condition of the front of Pine Rock is further proof of the action of the sea here supposed. The sweep of the tides across this region, would have some where made a tidal channel; and this channel, as the high terraces either side show, was that which after a while became, and now is, the outlet to the Beaver Pond, along the north side of the Beaver Hills (see map). In like manner, a depression was made in front of the larger part of Mill Rock, by encroachments upon Sachem's ridge. The disjunction was not so complete as in the case of the Beaver Hills, because the central basin of the bay, the Beaver Pond, gave no aid through its currents and waves, since it was remote from Sachem's ridge, while close along side of the Beaver Hills. As already observed, the streamlets descending the front of the Rocks after rains would have aided in the process of denudation, and with much greater effect after the elevation of the land which closed the Champlain era.

3. Life of the Champlain Era.

More than a score of years since, according to Mr. I. Lorenzo Stiles, the antlers of a buck were dug up at a depth of 10 or 15 feet at the Stiles clay-bed near North Haven village. Mr. Stiles informs us that they were those of the common species of deer. The specimen was deposited in the New Haven Museum, an institution which years since came to its end, and it has been lost sight of, so that the fact

with regard to its species cannot be verified. It is also stated by Mr. Stiles that impressions of leaves have been found in the clay. The muck at a depth of 6 to 12 feet has been found to contain at places great logs and stumps, nuts and leaves, accredited popularly (and probably rightly) to trees of existing species. But these are subsequent in age; for the muck beds of the interior of the basin could not have been begun until the salt-water harbor had been mostly obliterated by an elevation of the land.

The above is all we have yet gathered from the deposits of the New Haven region with regard to the life of this era. It is certain that there is much more to be learned; for there is good evidence of the existence of the Mastodon formerly in this part of Connecticut. While digging for the Farmington Canal in Cheshire, 13 miles north of New Haven, three or four teeth of a Mastodon were found, (Am. J. Sci., xiv, 187, 1828); and long before, remains of the same animal were obtained near Sharon. Also later, a vertebra of a Mastodon was brought to light in digging a canal for a manufactory in Berlin, the bone occurring in "a tufaceous lacustrine formation, containing bleached fresh-water shells of *Planorbis*, *Lymnæa*, *Cyclas*, etc., similar to those of the waters in the vicinity." (Am. J. Sci., xxvii, 165, 1835). This Berlin Mastodon existed as late as the Champlain era; for if of earlier time the lacustrine deposit would have been buried beneath drift, either the stratified or unstratified.

6. Terrace or Recent Era.

The work of the waves, tides and rivers went forward until the great drift formation of the bay and river valleys was completed. An elevation of the land then commenced which affected cotemporaneously all New England, and, it is believed, a large part of the continent, and bordered the rivers and lakes with terraces. This elevation marks the transition to the Terrace or Recent era.

1. Amount of Elevation.

In determining the amount of elevation of the land about the New Haven region, we have to take it for granted, not only that the plain was leveled off by the waters, but further, that a considerable part of its surface at the time nearly coincided with that of the water. The even character of the plain shows that this is not an improbable assumption.

The following are the results of the observations upon its level thus far made. The heights along the river valleys, the Beaver Pond ba-

sin, the valley of Pine-Marsh Creek and the borders of the bay are from approximate measurements, by means of a hand-level, by the author. The rest are from the large map of the city, published in 1858, from surveys and drawings by Mr. S. W. Searl. The distances from Oyster Point given are differences of latitude, or northings, in statute miles, and are derived from published maps. In reckoning the heights mean-tide level is taken as the base. The heights are not given of such parts of the terrace or plain as are obviously below the true or normal level (owing to river or tidal currents, or other causes), a fact generally made manifest by neighboring portions being at their full elevation.

I. Height of the surface along a nearly north-and-south course through the middle portion of the New Haven plain, from Oyster Point, by the College Square, to the Beaver Pond Meadows, and thence, half a mile to the eastward along the valley of Pine-Marsh Creek, (or as it is sometimes called Pine-Swamp brook).

	Northings from Oyster Point.	Height of Terrace.
Oyster Point	0 miles	21½ feet
In line with id., w. of West R.	0 "	24½ "
N. of Oyster Point	0·50 "	27 "
Halleck's Place, S. side*	0·75 "	30 "
" " N. side	0·87 "	30 "
College st., front of S. College	1·85 "	38 "
York street, corner of Broadway	2·00 "	41½ "
Beaver Pond basin, S. end	2·70 "	43 "
Id., E. end of Munson street Creek	2·80 "	43 "
Id., W. end of Munson street	2·80 "	44 "
Id., outlet, W. side	3·40 "	53½ "
Id., opposite outlet, on E. side	3·40 "	53½ "
Id., farther north, E. side	3·65 "	55½ "
Id., farther north, at road crossing	3·80 "	56 "
P. M. Creek valley, at southwest point	3·80 "	56 "
Id. at road crossing, N. W. of W. end Mill Rock	4·20 "	62 "
Id., farther north	4·30 "	63 "
Id., S. E. of Hamden Church	4·55 "	66 "
Id., at mouth of Creek	5·15 "	72 "

* The reader is advised to put a letter H on the map (p. 44) three-sixteenths of an inch north of the letter O, west of the harbor, and the letters G P on the point of land between the mouths of Mill River and the Quinnipiac.

II. Up West River valley.

	North. from Oyster Pt.	Height of T. in feet.
	0·20	23
Crossing of N. Y. railroad	0·50	27
End of Washington street	0·62	29
Crossing of Milford turnpike, W. side	1·25	36
North of Id.	1·40	37½
Above crossing of Oak st., W. side	1·85	38½
Crossing of Derby turnpike, W. side	2·25	41
" " " E. side	2·15	40
Crossing at Westville, E. side	3·15	46–47
Crossing at Westville, W. side	3·15	45–46
Near Congregational Church, Westville	3·45	56–57

III. Up Mill River valley.

Near Neck Bridge, east side, to highest point	2·00	42
Suydam Grounds, Whitneyville, W. side	3·30	53
Above dam, below 1st bridge, W. side	3·90	63
Whitneyville Church	4·40	66
N. of the Church	4·55	69
Mouth of Pine-Marsh Creek	5·15	72
Above mouth of Id.	5·60	76

IV. Up the Quinnipiac valley.

Foot of Third st., Fair Haven, near mouth of river	1·33	34½
Crossing of Shore-line R. R., W. side of river	1·80	40
North of Id.	1·90	41
Crossing of Air-line R. R., W. side of river	2·50	45
At North Haven	7·00	46

V. South of the latitude of Oyster Point.

On the west coast of the bay, 0·33 m. south of Oyster Point, the terrace is 24 feet high; 0·43 m., 21 to 23 feet; 1·30 m., at the Savin Rock beach, only 8 feet, but about 300 yards north, 14 feet.

In the following table the results in the preceding four tables are brought together for comparison. The Roman numerals I, II, III, IV, indicate the table from which the numbers below are taken.

North. from Oyster Point.	I. Middle of plain.	II. West River.	III. Mill River.	IV. Quinnipiac.
0·	21½–24½	21½		
0·20		23		
0·50	27	27		
0·62		29		
0·75	30			
0·87	30			
1·25		36		
1·33				34½
1·40		37½		
1·80				40
1·85	38	38½		
1·90				41
2·00	41½		42	
2·25		41		
2·50				45
2·70	43			
2·80	43			
2·88	44			
3·15		46–47		
3·30			53	
3·40	53½	56–57		
3·45				
3·65	55½			
3·80	56			
3·90			62	
4·20	63			
4·30	64			
4·40			66	
4·55	66		69	
5·15	72		72	

The Beaver Pond Meadows and the valley of Pine-Marsh Creek are natural levels, the former over a mile long, the latter three-fourths of a mile, each containing a range of nearly still water along the bottom through this distance; and hence the height of the terraces on either side is ascertained with great facility. It has already been stated that in the latter this water level is determined by the Whitneyville dam, so that the height of the dam gives, after an allowance for the back-water rise, the height of the water above mean-tide level, even for that of the upper part of the valley west of Mill Rock. The edge of the dam over which the water falls is 34 feet 8 inches above the base of the dam, according to Mr. Eli Whitney; and the surface of the water a few yards back is 4 inches higher, making in all 35 feet for the whole height of the fall. The base of the dam is very near mean-tide level. The back water above the dam extends about 2½ miles, to within 300 feet of the dam at Augerville; the increase in the height of the surface along this distance has been estimated to be about 6 inches a mile; or 15 inches for the whole distance, and 8½ inches to the mouth of Pine-Marsh Creek.

The elevation above mean-tide level of the water-surface in the Beaver Pond Meadows near its outlet, is taken at 22 feet, in accordance with information received from Mr. Eli W. Blake as to the heights of the dams between the Beaver Pond meadows and West River. A few hundred feet above the outlet of the *Beaver Pond basin,* the meadows commence a rising grade northward, as is obvi-

ous in the rippled surface of the little streamlet which flows along it; the increase of height thereby at the crossing of the road to Pine Rock (3·80 from O. P., in Table I) is at least 3 feet; and beyond this to the north the slope of the meadows runs parallel closely with that of the terrace plain either side, the height of the plain, even to its northern extremity, above the meadows being quite uniformly 31 to 32 feet.

The observations show that the plain rises gradually to the northward. The average increase of elevation from Oyster Point to the mouth of Pine-Marsh Creek, a distance of five miles, is 10 feet per mile. From Oyster Point to York street, two miles, it is 8½ feet; and to College street nearly 7¼ feet; from College street to the west end of the Munson street crossing of the Beaver Pond meadows, one mile, it is only 6 feet; along the Beaver Pond basin, from its southern end to the road which crosses it a little south of the line of Pine Rock, a mile in distance, the rise is 13½ feet; along the valley of Pine-Marsh Creek, the average per mile is about 12 feet. The slope for a mile north of College street, that is, between 1·80 and 2·80 miles in latitude from Oyster Point, is more gradual than either to the north or south; and the same is true for a surface of like latitude near West river, on which the increase in elevation from Oak street (1·85) to Westville (3·15), 1·30 miles in distance, is only 8½ feet.

The fact that the increase of elevation northward is by *a gradual slope, and not through a succession of two or more abrupt terraces*, is manifest along Dixwell Avenue (the road to Hamden Plains). The Avenue lies to the east of the Beaver Pond Meadows, and to the west of Pine-Marsh Creek, and extends northward in a nearly straight line, beyond the mouth of Pine-Marsh Creek; and hence any terrace would be apparent along its course, or in the fields either side, if such existed.

The observations prove the fact of an elevation of the land along this part of Connecticut after the Champlain era, the era in which the drift formation was made. They also appear to prove that this elevation was greatest, by a nearly regular rate, to the north. But before arriving at any conclusions as to the amount of elevation, or its rate of increase northward, it is necessary to consider:

First, Whether part of the slope above pointed out did not exist in the surface before the elevation began.

Secondly, Whether part of the slope was not formed by the retreating waters during the progress of the elevation.

Thirdly, Whether part is not a result of a sinking of the more southern portion of the plain since the elevation.

(1.) SLOPE ANTEDATING THE ELEVATION.—There can be no doubt that part of the slope antedates the elevation. This may be true of each end of the slope, that is (A) the *southern* part adjoining the bay, and (*B*) the *northern* part.

A. *The Southern Part.*—A slope in the southern part may have arisen (*a*) from the tidal currents with or without the waves, aided by the river floods; (*b*) from the waves alone; or (*c*) from increasing depth in the bay outward, and decreasing supply of sand.

(*a.*) *From tidal currents.*—Oyster Point projects toward the Sound between West River and the bay, and in this exposed condition would in all probability have been swept by the tides in such a manner that it would have failed to be built up to the water's surface or to mean tide level. The *eastern* part of this Point for the last half mile is actually half lower than the western or that bordering West river, owing undoubtedly to the action of the cause here mentioned; and the western suffered also; for, *on the other side of West River the terrace is* 24 *to* 24½ *feet high.* Grape Vine Point, a mile and a quarter farther north in the bay, is another example of this effect, as observed on page 72, where the facts as to its little height over its middle, and the western or Mill River side, and the full height of the terrace on the Quinnipiac side, are stated. Had the Point been a little narrower, it might have been low all the way across, so that it would have remained doubtful whether this low level was due to tidal currents or not. But the heights on the Quinnipiac side are as great as those of the middle of the New Haven plain in the same east-and-west lines, so that they have nearly the normal elevation. They show, therefore, that the lower part of the Point is over 20 feet below the normal level, owing to the action of the great central tidal flow up the bay. Again, at the corner of State and Chapel streets, along side of the channel of the old East Creek, the present height is 15 feet, or about 22 feet below the full height for the latitude; and this influence of the sweep of the tides is felt all the way nearly to an east-and-west line through the corner of College and Chapel streets.

It is quite certain, in view of these facts, that Oyster Point was in no part built up to the water level. How much to allow for the deficiency, we have not facts to determine. An allowance of 10 feet could not be too great; and this would give 31 or 32 feet as the height which the Point would have had, if no such cause had operated.

If the surface of the plain at Oyster Point, corresponding to the original water level, is to be reckoned at 30 feet above the present

mean tide, then the slope normal for the whole of the plain to the southern part of the Beaver Pond meadows, a distance of 2¾ miles, would not have been over *six* feet a mile.

b. From the waves alone.—The bay flats are a direct continuation of the flood-grounds or lower flats of the rivers entering the bay; and yet the former are leveled off at one-third tide, or lower, while the river flats and those of any sheltered coves may be very near high-tide level. The flats in the bay, like those outside, are washed by the waves and hence their lower level. If the surface is at one-third tide, as is the case with the flats off West Haven Point, there is then a difference of about 4 feet between their level and that of the flats or meadows along Mill river and the other rivers of the region. Consequently, *in a rise of the land the surface of the river flats would be* 3 or 4 *feet higher than that of the unprotected bay flats.*

When, however, the river flats are wet meadows, made of deep muck and oozy mud, they will dry and sink, and may thus lose all their excess of height, unless the flats are of so soft a mud as to settle equally. In the latter part of last century the tides were mainly shut out from the upper part of West River by a dam along the line of the bridge of the Milford Turnpike (see map) and, as a consequence, the meadow north of the dam is 1½ feet lower than that to the south. Those who know the history of the changes there attribute the difference of level to a fall in the surface from loss of water beneath; and this was doubtless the true cause. But, in the case of the river flats of the Champlain era, there is no evidence that they were topped by muck meadows; for in all the sections exposed to view they carry their sandy layers quite to the top. We may therefore reasonably assume that 3 to 4 feet of the excess in the *height of the part of the plain leveled by the river floods* above that of those along the bay, are to be attributed to the cause here explained.

c. Slope as a combined result of (a) *the increasing depth of the waters southward over the shallow border of the bay region, and* (b) *a decrease southward in the supply of sand*—the deposits as they extend southward consequently rising to a less and less height beneath the water's surface. The waters dropping their sands as they flow on through the bay would necessarily have had less for deposition about its outer portion. Part of the diminishing elevation of the plain in West Haven toward the Sound (p. 89), and perhaps something of that of Oyster Point, may have this explanation; and the latter may have been the principal one of the two causes here included.

B. *The Northern part.*—Somewhere across the New Haven region there was the limit of proper tidal action, or of the salt water flood-grounds, an irregular line bending north along the river valleys. [The northward bend for the rivers is much less than what the rise of the tides in the streams would seem to indicate; since this rise is largely due to the fresh waters being dammed up by the incoming tide; and in case of river floods, the fresh waters, and also something of the river slopes, may force their way to the bay, and even into it, in spite of the tides.] Whatever the position of this line, the plain to the north of it was made and leveled off by the river floods, and not by the tides. The slope of the surface in this upper part should therefore correspond with that of the waters in the flooded streams of the Champlain era.

It would be a great convenience if the sea had left its mark well defined across the plain; for then the present height of the former sea-limit would be easily ascertained. But all traces of a line of beach, if such there were, appear to be obliterated. We are left, therefore, to approximations from uncertain data.

We safely conclude that the land now at 30 feet elevation was within the range of the sea, for this is the height *directly on the bay*, at Halleck's; and further, that of 35 feet, for this is the height on the bay at the mouth of the Quinnipiac; and, moreover, the whitish sands overlying the terrace formation on what was the shore of the Quinnipiac harbor (p. 84), have a height of 35 feet notwithstanding the denudation they have undergone at top since their deposition.

Again, the part of the plain between 38 and 44 feet in elevation above mean tide is that which has the least slope, or is the most nearly level: and above it, or to the north, the plain rises at the rate of 11 to 12 feet a mile. There appears to be reason in this fact for placing low-tide, or mean-tide, limit near the line of 44 or 45 feet. If 44 were the low-tide limit, then high tide would have reached to the present 50 feet level; and the terrace formation, in the Suydam grounds below the Whitneyville dam west of the river, 53 feet high above mean-tide level, might have been the work of the sea water alone. *Fifty feet* as the *high tide* limit, would correspond to a difference of level in this region between the Champlain and Terrace eras of 50 to 51 feet, since the surface of the present river flats at Whitneyville is at high tide level.

Along the Mill River valley, above Whitneyville, the rising grade of 11 to 12 feet a mile for the plain continues not only to the mouth of Pine-Marsh Creek, but also nearly to Ives' Station; beyond, the *rate diminishes to* 10 and 9 feet, the latter occurring just below Mt.

Carmel. The height of the terrace-plain along Mill river is approximately as follows:

	Above the river.	Above mean-tide level.
At Whitneyville dam, (by calc.) . . .	55 feet.	55 feet.
1·40 m. N. of Wh., at mouth of P. M. Creek, (by calc.)	55 "	72 "
2·25 m. N. of W., at Augurville . . .	50 "	86 "
4 m. " ½ m. S. of Ives's Station	43 "	103 "
4½ m. " at Ives' Station,	41 "	108½ "
5¼ m. " south of Mt. Carmel gap	36 "	115 "

The heights above mean-tide level are obtained by adding the known height of the river at the several places mentioned (see page 101) to the height of the terrace. The height corresponding to the position of the Whitneyville dam is deduced from that at the Suydam grounds, a sixth of a mile below. The slope of the terrace plain up to the station half a mile south of Ives's station, according to the above, is 12 feet a mile, the quotient from dividing the difference of 103 and 55 by 4 (the distance). For the whole distance to Mt. Carmel, the average is about 11 feet a mile.

When it is considered that the waters which leveled this plain were the same that distributed the sand and gravel of the drift formation—that, in other words, the plain is only the upper surface of the drift formation then deposited, it is obvious that the water, to have made such a slope over so wide a region, even to the shores of the bay, must have been those of a flood of no common magnitude. For the last mile, the flooded waters of Mill River were united in one great tumultuous sea with those of western Hamden, or those of the several tributaries of Wilmot Brook, for the plain in this part has one level all the way across, a distance of three miles. Such a flood could hardly have come from any source but a melting glacier, and must have been simultaneous with the deposition of the material arranged by the waters.

The evidence that the drift formation north of the line of Whitneyville is attributable to the action of river floods, and not simply to an elevation of the land greatest to the north, is proved by the very different level of the terrace formation in the same latitudes in the Quinnipiac and Mill River valleys.

In the village of North Haven the stratified drift, *east* of the river, has a height in St. John street (a road ascending the west slope of a hill) near the northeast angle of the cemetery, of 40 feet above the river at high tide, or 43 to 44 feet above mean-tide level in the bay. The terrace plain is however poorly defined, and the hill rises gradu-

ally eastward to 61½ feet above high tide in the river;* yet the limit of the stratified drift formation is well marked beneath the surface; for the material of the part of the hill above 44 feet is much more compact than that below, and abounds in boulders or large stones promiscuously distributed, (many of them over a foot in diameter, and some very distinctly marked with parallel grooves from abrasion while in the foot of the old glacier),† showing plainly that it is *unstratified* drift.

On the *west* side of the Quinnipiac, the terrace plain (also here not very well defined) has a height of about 46 feet above mean-tide level.

Now this height of 44 to 46 feet (or perhaps 50 normally), at North Haven village occurs on the same east-and-west line with that of 103 feet in the Mill River valley. *If an elevation of the land were the cause of the increase of height northward, the two should have been alike.* The difference must be owing to the peculiarities of the two river regions. The Quinnipiac valley is that of a much larger river, has a much greater width as well as length, and opens toward the bay with a breadth of more than a mile. Moreover it descends to within four feet of the level of the sea at North Haven, four miles farther north than Whitneyville, a condition owing to the deep excavation of the basin in earlier time. The waters over such a basin would have been nearly level throughout, with only a small rise if the floods descending it were very great. The terraces therefore should have been but little above those at the southern limit of the basin between East Rock and Fair Haven, which is the fact; and hence the wide difference in height above the sea from what is observed in the Mill River region.

The conclusion that the amount of elevation was near 50 feet is sustained by the fact that the terraces on Mill River are at least 50 feet in height above the level of the river even as far north as Augurville, 2¼ miles from Whitneyville. The height of the terrace depends on the depth of the excavation after the elevation; and if the slope of the river's bed after the excavation is just what it was before, (provided the slope of the land had not been changed by greater or less eleva-

* According to leveling by Mr. D. H. Pierpont. An average tide rises 3¼ feet.

† The boulders lying on the surface in the southeast part of the Cemetery, (the part that is highest on the slope of the hill) were thrown out, as I learn from Mr. James H. Thorpe, in excavations for graves. On the *east* slope of this hill (or that away from the river), the stratified drift, judging from the loose sands of the surface, may extend *a little higher than* on the west side; but this point remains to be investigated.

tion to the north,) then the interval between the level of the terrace plain and that of the present flood-plain of the river (47 feet at Augurville) would just equal that of the amount of elevation. But in fact the river's bed at Augurville is 3 or 4 feet above what is required for a restoration of the earlier slope (p. 101), and not more than one foot of this 6 or 7 can be attributed to the rise of the land being greatest to the north; and hence 50 feet for the amount of elevation in the latitudes of Whitneyville and north to Augurville cannot be too great.

(2.) SLOPE MADE DURING THE PROGRESS OF THE ELEVATION.—Since the sand-flats of a bay have their height determined by the tides and waves, and are thus kept, for the most part, below mean tide level, a rise of the region exceedingly slow in progress might result in a wearing away of the surface at the same rate of progress; and thus the height of the sand-flats would be lowered, as the rise went on. But the material washed off from the flats would be carried to the shore to extend the beach seaward. The relation of the beach to the sand-flats may be seen along the shores near Savin Rock. As the rise went forward, the beach would keep extending; and as the beach attains a height by the accumulations, of only a few feet (three or four at Savin Rock) above high tide (the height of wave action), the final result would be a gradual seaward slope in the surface of the land, and one made during the progress of the elevation. But in such a case beach accumulations would have been laid down over the land to a depth of six feet or more; which would evince their origin by a dip in the layers of the lower part corresponding with the slope of the original beach, and an irregular arrangement of layers in the upper; if not, also, in the presence of beach relics.

Now, over the New Haven plain, all the way to Oyster Point, the drift formation in the numerous sections has a uniform horizontal stratification to the very top. The sands of the upper foot or less are discolored by the growth of vegetation, yet they are in fact a part of the upper layer. An overlying beach formation is nowhere distinguishable. There is therefore no certain evidence that any of the seaward slope of the plain was produced by the method here explained.

The facts tend to show that the elevation that placed Oyster Point and the land farther north above the sea was not slow in progress.

(3.) SLOPE RESULTING FROM A LATER SINKING OF THE SEA-MARGIN.—The evidences of a later sinking of the sea-margin to be looked for are the following: (1) Old stumps, in the position of growth imbedded in the flats or the shallow waters off the coast; (2) submerged remains of human structures; (3) submerged shell heaps

bearing evidence of man's agency in their accumulation; or (4) if the sinking is one now in progress, it should be apparent in the fact that the waters have deepened in historic times over submerged rocks, or in harbors. No proofs of such a sinking have been observed, and no one among those who have had the most to do with the coasts has suspected that any is now in progress.

The fact that the plain extends quite to the western hills, without any higher margin or range of beaches along these hills, is the strongest argument for the supposed sinking, that is, a sinking greatest to the southward.

(4.) Slope resulting from an increase in the amount of elevation to the north.—The great differences in the height of the drift formation in the Quinnipiac and Mill River valleys have shown that the slope in the surface of the latter is not due solely, or mainly, to an elevation of the land that was greatest to the north. The facts in Mill River valley would require, if this were the cause, an average increase in the rise northward of 11 feet a mile between Whitneyville and Mount Carmel; and those of the Quinnipiac, even taking the normal height of the terrace of North Haven at 50 feet, of but a foot a mile. Still it is possible that some part of the slope of the land is attributable to this cause, and even probable in view of the fact that the rise affected cotemporaneously all New England, and resulted in raising its northern portions, especially the northwestern, the most—the increase from New Haven, by Lake Champlain, to Montreal averaging 1½ feet a mile. Judging from the increasing height of the terraces to the northward along the rivers of Connecticut and Massachusetts, it does not appear probable that the increase per mile in southern New England exceeded *one foot* a mile. Adopting this rate for the New Haven region, the average slope of the part of the plain along Mill River valley, south of Mt Carmel, would be reduced to 10 feet a mile, and that of the part of the Quinnipiac south of North Haven, nearly to a level surface.

(5.) Conclusions with regard to the Elevation.—The following are the conclusions to which we are led with regard to the amount and character of the elevation.

1. That it was rapid if not abrupt, at least for the first 25 feet. (Progress for a century or two would be geologically rapid.)

2. That it was 45 to 50 feet, probably 50, in amount.

3. That the formation of the northern part of the plain, beyond 50 feet in elevation is due mainly to the floods of fresh water filling the valleys and spreading widely over the plains during the melting of *the great glacier* of central New England.

4. That not more than 1 foot a mile of the increase in the angle of the slope is due to a northward increase in the amount of elevation.

5. That part of the rapidity of slope in the lower portion of the plain below 40 feet in height, after allowing for a descent of the one foot a mile of §4, is due to tidal, wave, and river action over the region of the bay; and part to increasing depth over the borders of the bay southward; part to a decrease southward in the amount of transported sand.

6. That part of the slope in the lower part of the plain may possibly be owing to a slow sinking of the land along the margin of the Sound; but that there is no evidence that such a sinking is now in progress.

7. That the level of the terrace along Mill River above Whitneyville, and along the Quinnipiac north of North Haven may owe 3 or 4 feet of its height, as compared with that more to the south, to the fact that the surface of the latter was subjected to wave action because within the range of the bay.

But *may not this rise of* 50 *feet be only the final condition after a series of oscillations of level?* May not the land, when in course of elevation, have risen beyond 50 feet, even to 100 feet or more, and afterward have subsided to the present level? It is possible; for such an oscillation as this, performed in a brief period of time, would have passed unregistered. That the land has not stood at a level of 100 feet or so for any great length of time in the Recent or Terrace era may be inferred from the fact that, both at the outlet of Saltonstall Lake, and at the passage of Mill River through the Whitneyville gap, the trap dike over which the waters flow has not been worn away *below high tide level.* The gap intersecting the trap dike, (in fact a trap ridge) was in each case worn down toward its present condition in the Glacial era, as already observed. It is not at all probable that an elevation of the land could have again exposed both these valleys through a long period to the wear of waters flowing along them in rapids and descending in cascades of 50 feet or more, without at least one of them being worn to a lower level. The trap at Saltonstall Lake is soft and easily decomposable.

The rapids on West River for a mile above the bridge at Westville, are evidence that the channel has not been excavated, since the Glacial era, to a depth much below the present bottom.

It has been already stated that large stumps and logs occur in the Quinnipiac meadows. I am informed that it is a common thing to see them projecting from the banks at the very lowest limit of low water, or 5 or 6 feet below the level of the meadows; and some have been taken out and sawed into good boards. The wet meadows along

the rivers of Connecticut formerly were mostly under forests, and it is probable that this was true of those of the Quinnipiac. But stumps could not commence their growth at such a depth, and hence the position of the stumps and logs may seem to show that the level of the Quinnipiac meadows when these trees were flourishing, was a few feet at least above the present, and that consequently a slow sinking has taken place. The evidence appears to be sustained by the fact that the muck or peat in the meadows has great depth, for the lowest layer must have been near the present level of the meadows, when the plants of which it is made were growing. But the surface of a meadow may slowly subside, as growth goes on above, owing to the weight of the increasing accumulation of material; and large trees are known to sink in soft swampy soil as they attain large dimensions. The evidence therefore as to the fact of even the small elevation which is here suggested, is quite doubtful.

2. Results of the Elevation.

As a consequence of the rise, the rivers had at once a steeper slope than before to the sea; and hence, having new force for erosion and transportation, they set about deepening their beds, and the level also of the lower flats—making these lower flats mainly by encroachments on the terrace plain. They thus worked toward a restoration of the old slope at a lower level, or toward a slope still more gradual; and in the process, they made for themselves deep cuts through the drift formation and left the upper surface of the formation as a high upper plain or terrace. Until this change, the stratified drift formation was in no sense the *terrace formation.*

Along Mill River, between Mt. Carmel and the sea, the cut made was 35 to 55 feet or more in depth, as is indicated by the present height of the old flood grounds, that is, the terrace plain. The height of the terrace above the river's surface is—

A mile north of Whitneyville, (by calc.) - - -	51 feet.
At Augurville, 2¼ miles north of Whitneyville -	50 "
½ m. S. of Ives' Station, 4 m. N. of Whitneyville -	43 "
At Ives' Station, 4½ m. N. of Wh. - - - - -	41 "
¼ m. S. of Mt. Carmel, 5¼ m. N. of Wh. - - -	36 "

The height of the surface of the river above tide level, as derived mostly from the height of the dams,* with an allowance of 6 inches

* I am indebted for information on this point to Mr. Charles Holt. The height of the successive falls of water, north of the 35-foot fall at Whitneyville, are (1) at Augurville, 8 feet; ½ mile above, Webbing Company's dam, 8½ feet; ⅛ m. above, Beers's Grist Mill, 8 feet; near Ives' Station, James Ives' dam, 10 feet; at the Mt. Carmel gap,

per mile for the rise in the back-water above the dams, and as much more for descent above Augurville not included in the falls of the dams, is as follows at the different points here mentioned:—

2¼ m. north of Whitneyville, below the Augurville dam 36 feet.
4 m. N. of Whitneyville, ½ m. S. of Ives's Station 60 "
5½ m. N. of Whitneyville, below the Mt. Carmel dam 80 "
6 m. N. of Whitneyville, above the Mt. Carmel dam 92 "

It follows from the facts that the present slope of the bed of the river is about 15 feet a mile, while that of the terrace plain or old flood grounds varies from 13 to 9 feet a mile. The latter was the descent of the river in the Champlain era; and consequently the excavation which has taken place since the elevation closing that era has not wrought out as gradual a descent as the earlier, by *one to five feet a mile*, 1 foot a mile of the slope being taken as a result of an elevation of the land (p. 98, §4).

The height of the terrace corresponding to the line of the Whitneyville dam being 55 feet above mean-tide level (p. 95), its height *above the surface of the river* as it stood before the dam was built would be about 53 feet. Consequently, the amount of excavation that would be required at Augurville to restore the old slope would be 3 feet (50 feet being the height of the terrace above the river's surface) at Ives' Station, 12 feet; below the Mt. Carmel gap, 5¼ miles from Whitneyville, 17 feet; below the dam at the gap, 5½ miles from Whitneyville (where the terrace as deduced from the average slope in this part of the valley has a height of about 34 feet above the river's surface, though now abnormally lower), 19 feet.

At the Mt. Carmel gap there is a descent of 12 feet in half a mile, owing to the hard trap rock lying in the way of the river; but the terrace plain above appears to correspond in level with that below, that is, it has nearly the same slope and is almost in the same continuous plain. For while the river here descends 12 feet in half a mile, the depth of the cut made by the river through the terrace or drift formation north of the gap is only 26 feet—this being the height of the terrace plain above the river. The amount of excavation in this part of the valley would therefore have to be 27 feet.

These numbers, as already observed, are only approximations. For exact results, the slope of the bed of the river and the heights and slope of the terrace plain should be ascertained by more accurate

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F. Ives's dam, 12 feet; between the last two, 8 feet; in all 89 feet. The back-water of F. Ives's dam is less than a fourth of a mile in length, and its head about 6 miles in an air-line north of Whitneyville.

methods than by the use of a hand-level, ordinary measurements of the heights of dams, and estimates only of the slope of back water.

In the West River valley, the depth of the excavation made by the river is 45 to 48 feet in its lower part just above the limit reached by the tides, or near the Whalley Avenue bridge; but 1¼ miles (in an air-line) up the valley, near the Pond Lily Paper Mill and beyond, *it is only 7 or 8 feet.* The river therefore, to within 1¼ miles of the tidal limit, has a *level but 7 or 8 feet below that which it had in the Champlain era.* The plain spreads across this part of the valley and stretches far northward. But although showing so little elevation, it is actually *over 70 feet above mean-tide level.* The river has a descent of 72 or 73 feet from the head of back-water of the Pond Lily dam to the bridge, a distance of 1½ miles, in an air-line, which is equivalent nearly to 54 feet a mile.* There is also an unusually high angle of slope in the terrace plain of the valley, its height a mile and a half (1·50 m.) up the valley, being about 82 feet above mean-tide level; at 1·15 m. (Pond Lily dam), 72 feet; at 0·62 miles (below Parker's Paper Mill), 62 feet; at 0·3 miles (near the Congregational church), 56 feet; or in all about 24 feet a mile. These striking peculiarities of West river, may come partly from the valley being comparatively narrow; but they arise mainly from the fact that the terminating ridge of the Edgewood line of hills crosses the course of the stream just below the Pond Lily Paper Mill, and the passage cut through it for the waters is shallow. The bed of the stream in this part, as through all the region of rapids below, is made up of large boulders, and none of the schistose rocks of the Edgewood range are in sight; but they must lie not far below. The terrace plain, standing

* The falls above the Whalley Avenue bridge are as follows: 1st dam, 4½ feet; 2d or Beecher's dam, 8 feet; between 1st and 2d dams, 1 foot; 3d dam, or Mallory's, 9 feet; above Mallory's, (Parker's and the Pond Lily dams), 50 feet; in all, 72½ feet. The terrace near Beecher's dam is 42 feet above the level of the pond, and the pond is at surface 13½ or 14 feet above mean-tide level. The average course of the river from the bridge northward is about northeast, so that in 1½ m. in its direction there is only about 1 m. of northing.

I may add here, as an addendum to page 76, that just west of the Whalley avenue bridge, the oblique lamination in some of the layers of the terrace formation indicates the existenoe of a great river flood, or current southward, during the deposition; like that which existed, according to similar evidence, in the Quinnipiac. But east of the bridge, the oblique lamination has the reverse dip, and thus shows that, throughout the progress of the deposition quite to its close, the sands were under the action of waves and tidel currents *from* the bay and not that of the river currents. This region east of the bridge, as the map shows, is outside of the Westville valley, the river bending *in this part quite* far to the eastward.

high near the Whalley Avenue bridge, extends northeastward to a short distance beyond Parker's Paper Mill, and then is interrupted by this Edgewood ridge, the level of the road rising from 62 feet, that of the terrace plain, to about 90 feet. The ridge consists, to a considerable depth, of drift, and many boulders lie over its surface. Descending to the north, the terrace plain is again reached near Harper's Mill, but instead of being 39 feet above the bed of the stream, as near Parkers' Mill, it has the low height of about 8 feet above mentioned.

After the excavations were completed to their modern limits, the movement of the tides ascended West River to Westville; West Creek to Broad street; East Creek to Elm street; Mill River to Whitneyville; and the Quinnipiac to two miles beyond North Haven. East and West Creeks were the drainage streams for the surface between Mill and West rivers; and considering their little length, they were remarkable for the distance to which the tides ascended, for it was nearly half their whole length. They are now almost obliterated through the progress which man's "improvements" have recently given to nature's grading processes.

The Beaver Pond depression even in the earlier Champlain era had become partly filled up (probably because originally rather shallow); and after the elevation of the land its bottom was, as now, above the sea-level. But the present height of the Meadows does not give us the original level; what this height was we shall not know until we have ascertained what part of the present 22 feet above the sea is occupied by peat or other formations of the Recent or Terrace era.

At the same time that the rivers were cutting down their valleys the tides and waves were making encroachments on the coast deposits about the New Haven bay, and carrying forward a new system of tide-flats, sand-banks, and sea-beaches: and at this they are still at work.

Moreover, over the land, lakes were made shallower, and many were reduced to swamps or wholly dried up. Some of the peat or muck bogs had their origin in these swamps, while others date from the commencement of the Champlain era, if not before. The muck or peat of the Quinnipiac meadows must be mainly of the former, since in the Champlain era the region was deep under salt water. Part of what was formed along the borders of the old Quinnipiac harbor, however, may have begun in that earlier era, and if so, this part ought to indicate it by the remains of salt water grasses and infusoria. This remark applies also to the Beaver Pond peat meadows.

Through this elevation of the Terrace era over New England and the continent, by which rivers, lakes, and seashores were every where bordered by terraces, millions of square miles of land were raised from the condition of low flood-grounds to that of elevated plains, fitted for fields, dwellings, and cities, for which purpose they were afterward to be used. The New Haven plain was thus made ready to become to man a means of happiness and improvement, and also a source of gratitude for so goodly a dwelling place, although its larger river is the Quinnipiac and not the Connecticut.*

3. *Life of the Terrace or Recent Era.*—Of the wild animals which once inhabited the region in this Terrace era, only a single relic has yet been found. A stick cut by a beaver, from the Beaver Pond Meadows, was formerly in the possession of Eli W. Blake, Esq., but it is now lost.

Aboriginal man has left his heaps of shells at various points along the coast. There is a layer of them beneath the turf, on the shore of the bay between Halleck's place and Oyster Point. Others occur at intervals in a similar situation at the top of the terrace bordering West River above Oyster Point, as far as the cut made for the New York railroad; in West Haven, along the terrace near the mouth of West River; also, on and near the bay south of the mouth of West River, where the fields for a considerable distance from the shore are underlaid by them, so that the surface is thickly sprinkled with fragments of shells after ploughing; on Grape Vine Point; at the top of the high terrace on the west side of the Quinnipiac north and south of Fair Haven; also on the east of the Quinnipiac at various points, one of them at the corner of Church and Prospect streets in Fair Haven, just east of the Episcopal church, where a bed of this kind was laid open in digging a cellar for the house recently built on the spot.

The shells are either those of oysters, or the round-clam, and not of the long clam. Below Halleck's, and on Grape Vine Point, they are mostly of the round-clam; and at one place in the former region, many of the shells appear to have been burnt, and occur with fragments of charcoal. On the east side of West River, near the New York railroad, and on the west side along the terrace at its mouth, and also just south of the West Haven ship yard, oyster shells are most abun-

* See page 47. Saybrook has the mouth of the Connecticut river to which New Haven had a Triassic title; and New Haven has Yale College which Saybrook lost, after 16 years of possession from its foundation. If New Haven bay were now the mouth of *the Connecticut,* the site of the New Haven plain would be part of the bottom of the bay.

dant; but farther south along the coast of West Haven clam shells prevail. At Fair Haven, the shells are mainly oyster shells.

I have looked among these heaps thus far in vain for flint arrow heads and other Indian relics.

Along the West Haven shore on the bay broken shells of the scallop (*Pecten irradians*) and of the large "winkle" (*Fulgur carica*), are occasionally met with. Two bones were found among the shells that had fallen from the edge of the terrace, which I have put into the hands of Professor Marsh, our palæontologist, for examination. One he reports is from the leg of a deer, and the other is probably from that of a wild goose. No distinct traces of charcoal or of burnt shells have been observed, except along the coast south of Halleck's place. The Indian evidently ate his clams as well as oysters in general without cooking. This is evident also from the broken condition of the clam shells. They look as if they had been treated like walnuts.

The shell beds often lie directly upon the brown or yellow sand or gravel of the drift formation, evincing that the Indian inhabited the plains before the alluvium had been covered with, or converted at top into, soil. But no instance is yet known of their occurrence beneath any of the beds of the stratified drift, or under the drift of the hills. They carry back the appearance of man in the region to the commencement of the Terrace or Recent era; and not beyond this.

7. Wells in the New Haven plain.—Hard-pan beneath the bay.

There are two series of facts bearing upon the geological structure of the New Haven region which should be here alluded to, although the subjects require farther investigation. One relates to the depth and source of the subterranean waters; and the other to the existence and nature of a compact layer, or hard-pan, beneath the muddy bottom of the bay and the beds of the adjoining parts of the rivers.

1. Wells.—The following facts with regard to the *subterranean waters of the plain*, as illustrated by its wells, I have from Mr. D. W. Buckingham, and Mr. Philo Chatfield, whose personal observations in this direction have been extensive.

(1.) The water is spread widely beneath the plain, and is not collected in local channels; this accords with the sandy nature and horizontality of the deposits that afford it.

(2.) The height of the water varies with the degree of humidity of the seasons, the extreme difference amounting to about two feet; it is ordinarily about three years in reaching its lowest level, and as many in regaining its highest.

(3.) In digging wells, water is not usually found until a firm gravelly layer is reached.

(4.) Over the central portion of the New Haven plain, about High street, back of the College grounds, and to the north, water is obtained wherever the height is near 40 feet, at a depth of about 26 feet—in other words, the upper limit of water, or the water-plain, is here about 14 feet above mean-tide level; and the height of any spot over this region being ascertained, the number of feet of excavation required to reach water is at once almost exactly known. To the southeastward the water-plain dips toward the bay; its height at the corner of Church and Chapel streets, one-fourth of a mile from High street, (where the height of the surface is 20 feet) is 6 feet, or 14 below the surface; and one-sixth of a mile farther southeastward, in State street near Chapel (where the height of the surface is 14 feet), it is about 3 feet, or 11 below the surface. Through Chapel street, between Church and State, and over the region either side, the depth to water is 12 to 14 feet, and in State street 11 to 12 feet. On the southwestern border of the High street region, along Oak street, the course of the old *West Creek* channel, water rises nearly to the surface, or to a level of 12 or 13 feet above the sea, the land here being low. Again in Grove street, on the other margin of the High street area, near the Cemetery, in the old *East Creek* channel, the water-plain is 20 feet above the sea; Sachem's ridge is near by.

In contrast with the above, we find that to the northwest of what we have called the High street region, beyond Dwight street, the water-plain dips toward West river, and falls even below the mean level of the water in the river, or that of the bay. Thus out West Chapel street, not far from its junction with the Derby Avenue, (where the plain has a height of 37 to 40 feet), wells are sunk to a depth of 50 feet before water is reached; the latter depth is 10 feet below the level of the sea and of the river. I learn from Mr. P. Chatfield that the excavation for the well at the house now occupied by Mr. G. H. Scranton, near the residence of Mr. E. Malley, was carried to a depth of 45 feet. Again, out Whalley Avenue, at Hamilton Park not far from West River, the depth to water is 45 feet. But on Hudson street, west of the jail, on Whalley Avenue, the wells are only 25 feet to water. Hudson street is therefore within the limits of the central *high-water* region of the city, while Norton street is beyond it.

In addition to these facts respecting subterranean waters derived from wells, there is another having an important bearing upon the *subject* connected with the great Beaver Pond depression. This ba-

sin, lying to the north of the High street region and but three-fourths of a mile from the College Square, is supplied through springs with an abundant and perpetual flow of water, making a stream of considerable size, which has its mill privileges like the rivers from the hills (p. 53.) *The level is constant at about* 22 *feet above the bay.* Formerly, before the deepening of its outlet, it stood at 24 feet, and 50 years since its ponds often afforded good skating in winter. To what height the springs would carry the water, if the outlet were dammed up to a higher level, is not known.

In this position of the Beaver Pond Meadows with reference to the plain, and in that of the adjoining Beaver Hills, we appear to have a partial explanation of the facts observed. The Beaver Ponds lie at the eastern foot of the Beaver Hills, and just southeast of the Pine Rock ridge. Now the dip of the sandstone in the New Haven region is almost uniformly either to the eastward or southeastward; it is southeastward, as observation shows, in the western part of Pine Rock; and probably south of east in the layers (now nowhere exposed to view) that underlie the Beaver Hills. There can hardly be a doubt that the Beaver Ponds owe their waters chiefly to the dip or inclination of the strata in these hills, this being just such as would throw the main part of the water that falls upon them in that direction. Further, the Beaver Hills extend southward and cross Whalley Avenue in the vicinity of North and Norton streets, and probably extend under ground much farther south. They consequently make a *western boundary* to the northern part of what we have called the High street area. Hudson street and the jail are *east* of the line of the Hills, and therefore, within the high-water area; while Hamilton Park is to the *west* and far outside of it. It would seem natural therefore that this area, having the water works of the Beaver Hills and Ponds on the north to aid the rains that fall over the surface in the wet season, should be supplied with water freely, and at a considerable height above the level of the sea; and at the same time that the region toward West River, to the west of the Hills, or of its line, failing of benefit from the dip of the rocks, or from the Beaver Ponds, (or deriving less benefit, if any) should require deeper excavation to reach water.

But the condition here explained can hardly be the sole cause of the difference between these regions; for the existence of so free a supply of water over the former would seem to require a partially hardened gravelly, or else a clayey, layer, ("hard-pan,") beneath to prevent waste; and the position of this layer would naturally affect

the level of the water. But on this point we have no facts, since the wells over the plain have never been sunk so deep as to reach such a layer, nor even below a depth of forty feet. If the Beaver Pond depression was once, as supposed, a central basin of the harbor, it is likely that there is such a layer beneath.

Some facts respecting *Artesian Wells* are mentioned beyond.

2. Hard-pan of the harbor.—The following observations on the *hard-pan* beneath the harbor consist mostly of information obtained through the driving of piles, and the sinking of Artesian Wells. For the facts derived from pile-driving I am indebted mainly to Mr. C. R. Waterhouse, whose occupation has given him numberless opportunities for observation.

a. At the head of the bay, near the foot of Greene street, in preparing the foundations for the Gas Works, a *hard-pan* layer was found at a depth of 31 feet below the level of the sea; the overlying material being harbor mud. The layer was 3 feet thick. On driving through it, by way of experiment, the piles went down through 40 feet of mud or loose sand, without finding another hard layer.

b. In the construction of the Chapel street bridge across the mouth of Mill River to Grape Vine Point, a little south of the Gas Works, the piles, starting from mean-tide level, penetrated 33 feet of mud and struck the hard-pan. The layer was so hard that the piles made but an inch or two at a stroke, and with 54 strokes did not go through it.

c. At the steamboat dock, 120 rods farther south, the piles passed through 25 or 26 feet of mud before reaching the hard-pan.

At the end of Long Wharf, two-thirds of a mile outside of the old coast line, and near the deep-water channel of the bay, the hard-pan was reached at a depth of 45 feet below mean-tide level; 13 of the 45 feet being water, and 32 mud.

d. In the construction of the new Long Wharf for the Canal railroad, situated only twenty rods east of the old Long Wharf, and extending to the same deep-water channel of the bay, the piles, at the extremity, and for the greater part of its length, as I learn from Mr. Yeamans, the Vice-President, were driven down 43 to 45 feet below mean-tide level, the longest being those between its middle and the land. In driving other piles over the old Canal basin (which adjoins the wharf on the north) it was found that a region of very deep mud extended eastward not far outside of the present line of yards and buildings, which was evidently the former submarine bed of the old *East Creek* channel (whose waters it will be remembered, had their discharge into this Canal basin at its head, just east of the old Long Wharf, and close

by the commencement of the new wharf). In the eastern corner of this basin, after crossing this mud-channel, a hard impenetrable bottom was found at 18 to 20 fathoms.

e. In driving piles for the bridge of the New York Railroad, across West River, toward its mouth, the hard-pan was found at a depth of 35 to 40 feet; and for the Derby Railroad crossing, a little farther north, at 25 to 30 feet; in one case 40 feet. In these, and other cases, the layer was not so thick but that the piles could be driven through it, and when thus passed, they descended many yards before finding good bottom again.

f. The piles for the Air-line railroad, over the Quinnipiac meadows, found a hard bottom at a maximum depth of 40 feet.

g. Last year piles were driven in the *West Creek* region, near the southeast corner of Congress Avenue and Oak street, which descended 20 feet before striking a hard bottom.

h. An artesian well sunk by the Messrs. Trowbridge on Long Wharf, about 350 yards outside of the old coast line, found a supply of fresh water, but slightly brackish, in a layer of gravelly hard-pan at a depth of 20 feet, or 14 feet below mean-tide level.

i. Another artesian well, on the same wharf, but 400 yards farther from the old coast line, made by Mr. Aaron Kilburn, under the direction of Capt. S. J. Clark, found water at a depth of 56 feet. The boring (6 inches in diameter) passed through 28 feet of mud; and then about the same thickness of earth resembling the ordinary sand beds of the plain, without any large stones; and the water at first rose to a height of 6 feet above the top of the wharf. Allowing for the height of the wharf, and the penetration of the hard-pan to a depth of 3 feet, the layer here lies 45 to 48 feet below mean-tide level. The depth consequently was very nearly the same with that ascertained by pile-driving at the end of the wharf.

j. At the Staples Block Factory, on Long Wharf, just north of the Messrs. Trowbridge, an artesian well was sunk by Mr. Kilburn to a depth of 45 feet below the surface of the wharf, or 39 feet below mean-tide level, and perfectly good fresh water obtained. The boring passed through 32 feet to the bottom of the mud, then through sand and gravel like that of the New Haven plain, in the course of which there were 2 feet of hard blue clay, a very hard hard-pan, as Mr. Kilburn describes it.

k. In another artesian boring, made by Mr. Kilburn, at the depot of the New York and New Haven railroad, east of the commencement of Long Wharf, good water, entirely free from brackishness, was obtained.

at a depth of 68 feet, or about 60 feet below mean-tide level. The boring passed through 36 *feet of harbor mud*, and, below this, through *sea-shore* or *worn sand*, which was coarser below. The great depth to water at a point so far inside of the Trowbridge and Staples wells, and also the thickness of the deposit of mud, are accounted for by the fact that the place was just within the mouth of the *East Creek* estuary.

[It may be added here, although not exactly relevant, that an artesian boring by Mr. Kilburn in Howard street, opposite McLagon & Stevens's factory, descended through 60 feet of quicksand, and struck the solid sandstone rock at a depth of 68 feet. The sandstone was that of the underground slopes of Sachem's ridge.]

l. In Greene street, at the India Rubber Works, about 50 rods above the Gas Works, an artesian well was sunk, under the direction of Mr. H. Hotchkiss, to a depth of 250 feet. But the existence of a hard layer was not noted, and is uncertain. The material passed through was mainly like that of the plain for 140 feet; then followed a bed of "splendid" clay, 14 feet thick; and below this the same essentially as above. At the bottom the tubing was badly bent by striking against something supposed to be rock, and the boring was consequently suspended. It is not known whether the rock was solid sandstone or a loose mass.

1. The facts show that a hard layer, called *hard-pan*, may be reached beneath the harbor, and the estuary part of the Quinnipiac and West Rivers, at depths mostly between 30 and 45 feet; that its depth along the north side of the deep-water channel of the bay is 40 to 45 feet; that this continues to be its depth through nearly two-thirds of the line of the Canal railroad wharf (which is much farther shoreward than along that of Long Wharf, owing to the fact that Long Wharf was built out as the extension of a sandy point between East and West Creeks, while the new wharf is situated off the mouth of East Creek); that toward the shore the depth of the hard-pan generally decreases.

2. That the hard-pan is one of the layers of the stratified drift, that is, of that portion of the drift which was deposited over the bottom of the bay and rivers.

3. That the layer varies in thickness; that it may generally be penetrated by a continued driving of a pile; and when passed, the pile goes easily through a great depth of material before another hard layer is found; and that this soft material beneath the first hard-pan

layer, although sometimes described as mud, is probably wet uncompacted sand or gravel.

4. That the hard-pan *may be* in most cases the *same* particular layer of the drift formation; but that we do not know facts enough to authorize the assertion that this is true; or enough to establish satisfactorily its probability.

5. That the hard-pan in some cases is probably a gravelly layer firmly compacted. The region north of the head of the harbor, in the direction of the Canal railroad and the Mill River valley, is underlaid, as has been shown (p. 71) by a very coarse gravel, as the result of the central tidal flow of the bay in connection with the currents of the streams; and it is probable that this gravel-course extends out beneath the harbor; and this may be the hard-pan layer that is reached by the piles. It would naturally have an inclination seaward, following the slope of the bottom of the bay. Along the valley of West River and that of the Quinnipiac, there were doubtless similar gravelly layers formed below, through like means, which may be the hard-pan encountered in the beds of these streams. Yet this is only a suggestion, to be tested by future examination. None of the hard-pan has ever been brought up to the surface, and nothing positive is known as to its nature or the cause of its hardness. It may owe its hard-pan quality to a partial cementing of the material by means of oxyd of iron, an ingredient always present in the sand and gravel and the source of the prevailing color, and often causing the waters that flow through them to become strongly chalybeate; besides being a common cement among rock strata. But the coarse gravel beneath State street and the Mill River region is in almost all parts very hard digging, owing to its firmness, and for thick beds perhaps nothing more in the way of firmness would be required than what here exists.

6. That the hard-pan layer is usually sufficiently water-tight, or close in texture, to carry fresh-water along it from the land, following its seaward slope, and thence to become a source of fresh-water for artesian wells in the harbor. The flow of fresh water in a layer beneath the bay is evidence that this layer probably continues inland, and is a seaward part of a sloping water-bearing layer beneath the plain. The fact that the wells of the central and lower part of the New Haven plain generally descend into a gravelly layer is favorable to the view that the hard-pan is gravelly. Yet a layer of clayey sand is equally retentive of water, and will as well hold up the fresh-waters flowing seaward from the land; and when the wells of the plain as

well as those of the harbor are farther investigated, it may be found that there is an impervious layer of this character beneath the water-bearing one.

We may add here one conclusion respecting East Creek. The facts teach that this estuary has a deep under-bay channel; and such a channel as could have been excavated only by fresh waters when the land was at a higher level than now. This era of higher level was probably that of the old glacier. The 36 feet that were occupied with mud in the artesian boring at the railroad depot (p. 109, § *k*) are only a part of the whole depth of the excavation; for the sands and gravel of the drift must lie beneath. The depth to which the mud extends here and over the harbor is probably an indication of the depth of water in the channel and bay, in the later Champlain or earlier part of the Terrace or Recent era; and when the mud deposit has been sounded throughout we shall have some idea of the topography characterizing the bottom of the New Haven bay at that time.

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